BBC SECRETS OF THE UNIVERSE'S BIGGEST STARS

#216 MAY 2023

Sky at Night

THE UK'S BEST-SELLING ASTRONOMY MAGAZINE

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MOORS & DALES

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SCAN THE QR to discover more!

Welcome

Join us for some stargazing under beautiful dark skies

When light pollution is brightening the night at an increasing rate, it's heartening to see some regions taking steps to protect their dark skies. Jamie Carter travelled to Yorkshire to experience the UK's newest International Dark Skies Reserves, the North York Moors and the Yorkshire Dales. Turn to his article on **page 60** to bask in the starry skies, hear what locals did to achieve dark-sky accreditation and find out how to make a visit there a truly stellar experience.

Stellar experiences don't get much bigger than hypergiants. These are the behemoths of the Universe – if there was one at the centre of the Solar System, everything out to the orbit of Saturn would be within it! And because of their size, hypergiants display some truly mysterious behaviour, regularly shedding staggering amounts of mass, often more than Jupiter at one time. But as Colin Stuart reveals in his feature, new research is offering a convincing explanation for these outbursts. Discover more on **page 34**, including where to find a hypergiant star for yourself in the night sky.

Such mammoth objects are few and far between – astronomers know of just 10 among our Galaxy's 100 *billion* stars. With those numbers of stars, it's no wonder our Galaxy is a glittering band stretching across the dark sky. It's a beautiful sight to photograph in summer, and on **page 28** you'll find Will Gater's beginners' guide on exactly how to do it.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 18 May.

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Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

Online
Visit our website for competitions, astrophoto galleries, observing guides and more

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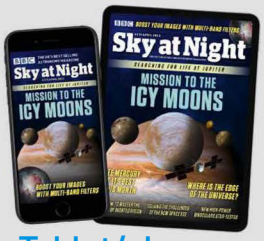
Listen to our Radio Astronomy podcasts where the magazine team and guests discuss astro news



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16-PAGE CENTRE PULLOUT

COVER IMAGE: PETE COLLINS, THIS PAGE: WILL GATER, ESO/M. KORNMESSER, @THESHED_PHOTOSTUDIO, NASA, STEVE BELL, CFA/M. WEISS, NASA W. LILLER/RICHARD GOODRICH

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**

This month's contributors

Jamie Carter

Astronomy journalist

"It was a treat to go stargazing under some truly dark skies in Yorkshire, but also to meet the passionate people working hard to reduce light pollution." **Jamie Carter enjoys the moors' pristine skies on page 60**

Jane Green

Astronomy author

"It's hard to believe it's 50 years since the launch of Skylab, the US space station that paved the way for our current age of long-duration spaceflight." **Jane explores the trials and tribulations of Skylab on page 66**

Anita Chandran

Science writer

"Dark matter is one of the Universe's most elusive substances. It was fascinating to dive into Piña's research on the mysterious galaxies that appear to contain none at all." **Anita talks to dark matter scientist Pavel Piña, page 98**

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/KZRG5FS** to access this month's selection of exclusive Bonus Content

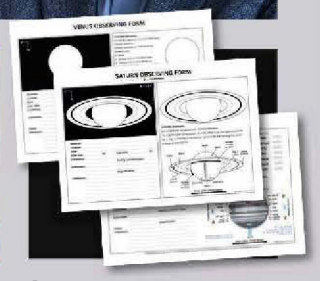
MAY HIGHLIGHTS

Interview: Comet Madness of 1910

Historian Richard Goodrich explores some of the public hysteria around the 1910 appearance of Halley's Comet

DIY Astronomy: Build an artificial star

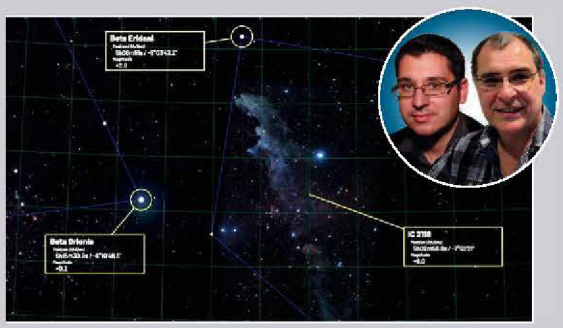
Download extra plans and images to help with this month's DIY project: a tool to test the quality of your scope and lenses (page 74)



Access extra observing materials

Download and print out forms that you can use to sketch and record your planetary observations throughout the year

The Virtual Planetarium



DUST TO DUST

As this massive star dies, its cosmic dust holds the ingredients out of which new planets may form

JAMES WEBB SPACE TELESCOPE, 14 MARCH 2023

Nothing can last forever, and as some massive stars reach their final moments, they live briefly as Wolf–Rayet stars. This one, Wolf–Rayet 124, or WR 124, is found in the constellation Sagitta, some 15,000 lightyears away.

WR 124 is 30 times the mass of our Sun, and its surrounding nebula, M1-67, is 10 lightyears across. But the star is losing material rapidly, pushing out elements like helium, nitrogen and carbon as cosmic dust – elements that were key to the formation of stars and planets in the early Universe, and which may precipitate new bouts of star formation in the future. This dust is best observed in infrared, and Webb's powerful instruments pick out the clouds ringing WR 124 with stunning clarity.

So far, scientists estimate that WR 124 has shed 10 Suns' worth of material, and it'll continue to lose mass as it heads toward its dramatic ending as a supernova. Whether the elements in WR 124's dust will survive the star's fatal explosion, we just don't know.

MORE **ONLINE**

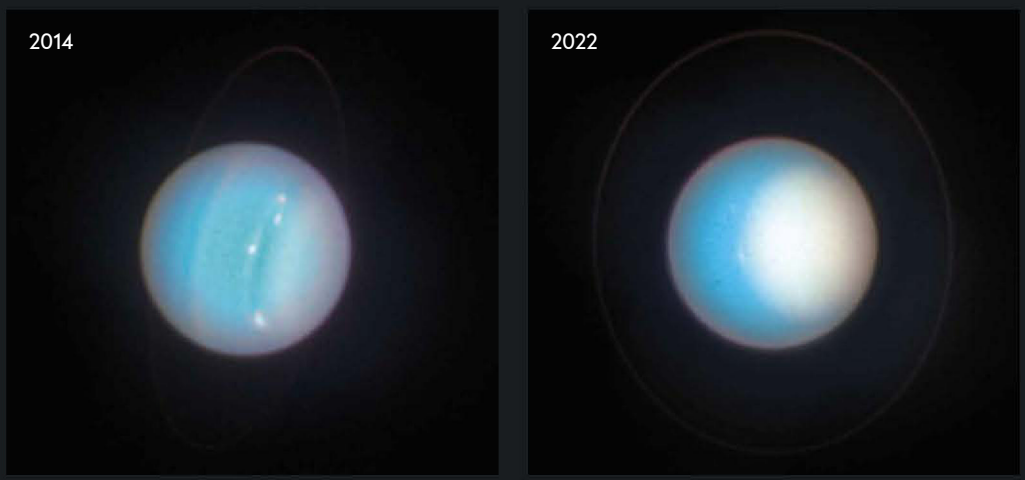
Explore a gallery of these and more stunning space images

NASA/ESA/CSA/STScI/WEBB ERO PRODUCTION TEAM

△ Weathering the storm

NASA SOLAR DYNAMICS OBSERVATORY, 23 MARCH 2023

A huge coronal hole on the southern hemisphere of the Sun saw the US Space Weather Prediction Center put in place a 'geomagnetic storm watch' in late March. Coronal holes are regions of open magnetic field lines where the solar wind escapes more readily. These geomagnetic storms were rated 'moderate', but storms can affect the power grid, satellites and the behaviour of migratory animals, as well as causing increased aurora displays.



△ Ice giant's brightening cap

HUBBLE SPACE TELESCOPE, 23 MARCH 2023

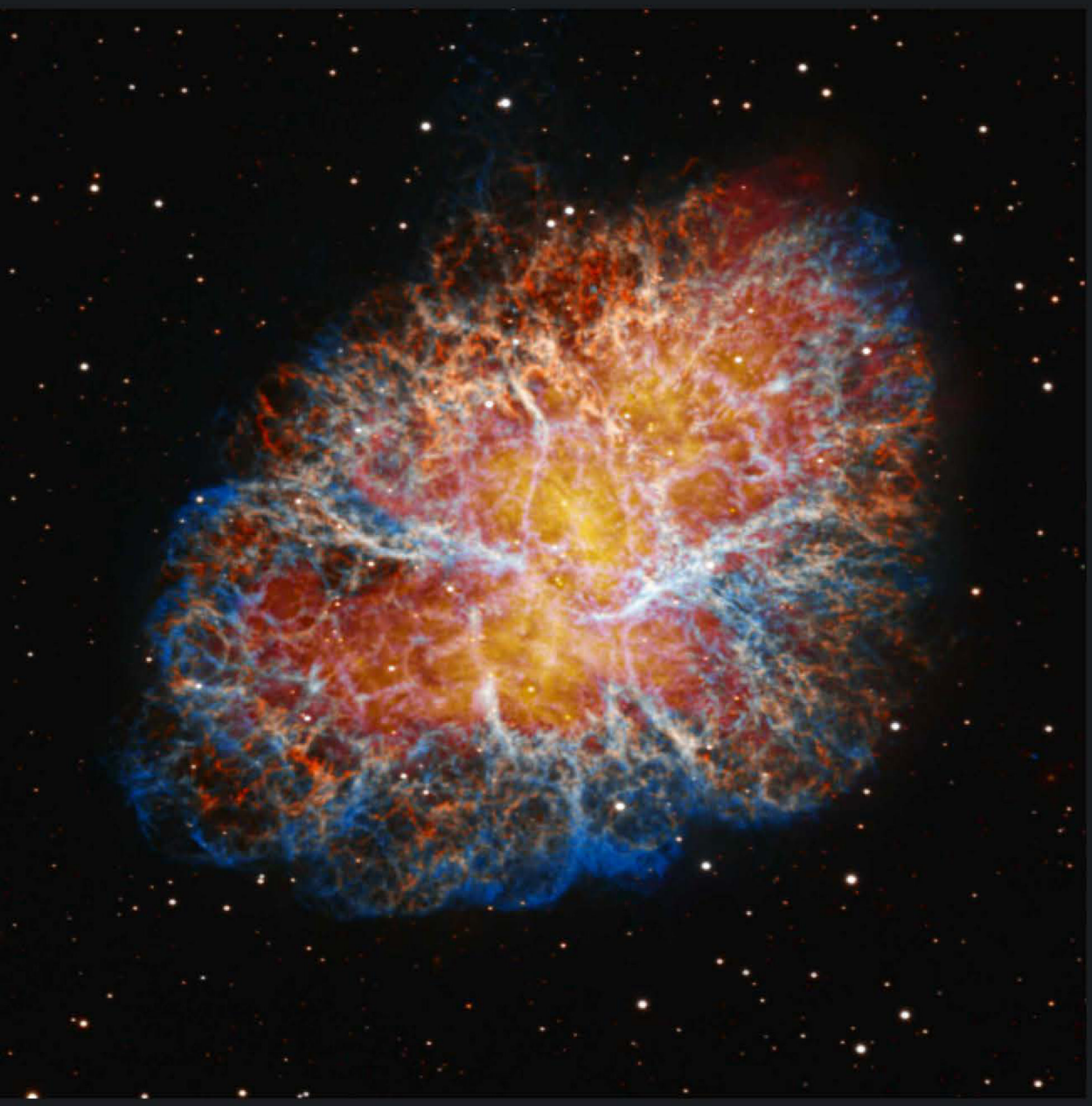
These Hubble views show changes at Uranus over eight years. Left, storms of methane-ice clouds are dotted against the light-blue lower atmosphere, the ring system slightly tilted. Eight years later, the ring is virtually face-on, the north pole covered in thick haze. This polar region is brightening every year and, by northern summer solstice in 2028, it and the ring will be face-on, giving us a wonderful view of the mysterious, blue ice giant nearly 3 billion kilometres away.

NASA SOLAR DYNAMICS OBSERVATORY, SCIENCE: NASA/ESA/STSCI/AMY SIMON (NASA-GSFC)/MICHAEL H. WONG (UC BERKELEY)/IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI), ESA/HUBBLE & NASA/M. GULLIEUSZIK AND THE GASP TEAM, KPNO/NOIRLAB/NSF/AURA

Jellyfish out of water ▷

HUBBLE SPACE TELESCOPE, 20 MARCH 2023

As galaxies move in space, some encounter gas clouds that, as they have here with galaxy JW100 in the constellation of Pegasus, act almost like a wind. Gas and dust from the galaxy have been stripped out in tendrils that hang behind JW100, leading astronomers to refer to it as a 'jellyfish' galaxy. Observations of these galaxies by Hubble help us understand how stars can sometimes form in the jellyfish's 'tentacles'.



◁ Crab in colour

NICHOLAS U MAYALL TELESCOPE, 15 MARCH 2023

M1, the Crab Nebula, is a supernova remnant thought to have exploded in 1054. At its heart is a neutron star, the Crab Pulsar, which emits radiation detectable by instruments like the Mayall telescope. You'd be forgiven for failing to see a crustacean here – the name stuck after astronomer William Parsons, the Earl of Rosse, made a crab-like drawing while viewing M1 in 1844 through his 36-inch telescope at Birr Castle, Ireland; though even he couldn't see the likeness upon second viewing.

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

Big or small, every legacy gift left to the Stroke Association will make a difference to stroke survivors and their families.

Find out how by calling 020 7566 1505

or email legacy@stroke.org.uk

or visit stroke.org.uk/legacy

Rebuilding lives after stroke

Stroke Association

The latest astronomy and space news, written by Ezzy Pearson

BULLETIN

▲ Plans are coming together, with the rocket stages now connected and the debut of new comfy spacesuits

Artemis II on track for 2024

The first woman should set foot on the Moon the following year

NASA is on track to put the first woman on the Moon within the next few years, after a review of the initial Artemis I mission found no major issues.

The uncrewed Artemis I launched on 16 November and, after several scrubbed launch attempts, proved extremely successful. NASA carefully examined the Orion crew capsule and discovered one of the few problems: the capsule's heat shield had not ablated as predicted, although there was still margin for error.

NASA is confident it can remedy several other minor snags and stay on track to launch the first crewed test, Artemis II, in November 2024. At the end of March, the five core stages of the Space Launch System (SLS) rocket were connected together and are due to be shipped to the Kennedy Space Center this summer. Around the same time, the Orion crew and service modules will be joined together ready to be stacked with the SLS in the first quarter of 2024.

If all goes well on that test flight, the first landing mission, Artemis III, should follow around a year afterwards. However, this timeline depends on the private companies which are providing several key systems also progressing on time. Among these is the Starship Human Landing System (HLS) from SpaceX, which will rendezvous with Orion en route to the Moon then carry the crew to the lunar surface. The first test flight of the Starship system is expected this April.

Once on the surface, the crew will rely on new spacesuits under development by Axiom Space, which were debuted this March. These are designed to be more comfortable and flexible, and accommodate a broader range of body shapes than existing suits. "Axiom's next generation spacesuits will not only enable the first woman to walk on the Moon, but they will also open opportunities for more people to explore and conduct science on the Moon than ever before," says NASA administrator Bill Nelson.

www.nasa.gov/artemisprogram

NASA X 3

Comment

by Chris Lintott

We don't have to wait for Artemis II to get excited by missions to the Moon, as a whole fleet of small, robotic missions are hoping to reach the lunar surface in 2023. Built by commercial companies but paid for by NASA, several of these are exploring new territory or doing new things. IM-1 will touch down on the edge of a crater near the lunar south pole, where future astronauts are likely to go. It will be joined by IM-2, with a drill to look for water ice under the surface. Peregine-1 will study the Moon's exosphere, the closest thing it has to an atmosphere, and Japan and India are planning lunar trips too. From these missions we'll learn plenty, without putting a single bootprint on lunar soil.

Chris Lintott co-presents *The Sky at Night*

▲ **Astrobiologists discovered several kinds of amino acids, the building blocks of all known forms of terrestrial life**

Asteroid Ryugu rich with life-giving chemicals

Organic molecules found in first full sample returned directly from an asteroid

Asteroid Ryugu is rich with organic molecules, according to the first analysis by an international team looking for these key life-giving ingredients. The rock was brought back to Earth by the Japanese spacecraft Hayabusa2. The discovery lends weight to the idea that asteroids helped transport organic chemicals to early Earth.

The molecules discovered in Ryugu are a wide range of compounds, which on Earth form the building blocks of all life. They don't require life to form, however, and some of them are even created in space. They've been spied in the discs of dust which planets grow from, but it's not well understood how these molecules make their way from space to a planet's surface.

The analysis – performed by teams across Japan, Europe and NASA's Goddard Spaceflight Center – uncovered amino acids, organic molecules which terrestrial life uses to form proteins. "These molecules can be transported throughout the Solar System, potentially dispersing as interplanetary dust particles after being ejected from the uppermost layer of the asteroid by impacts or other causes," says Hiroshi Naraoka from Kyushu University, Japan, who led the study.

The amount of amino acids was similar to that found in carbon-rich meteorites, but Ryugu was found to lack the sugars and nucleobases which make up DNA and RNA, and which have been found in many such space rocks.

"It is possible these compounds are present in asteroid Ryugu but are below our analytical detection limits, given the relatively small sample mass available for study," says Daniel Glavin, astrobiologist at Goddard Spaceflight Center and a co-author of the paper.

Hayabusa2 brought back just 5.4g of material, which was collected from the asteroid on 22 February 2019. A sample of just 30mg was extracted and prepared for organics testing, ensuring there would be enough remaining to allow for more tests in the years to come.

"We will do a direct comparison of the samples from Ryugu and the sample from asteroid Bennu when NASA's OSIRIS-REx mission returns it to Earth in 2023," says Jason Dworkin, also from Goddard, who took part in the study.

"OSIRIS-REx is expected to return much more sample mass from Bennu and will provide another important opportunity to look for trace organic building blocks of life in a carbon-rich asteroid."

www.nasa.gov

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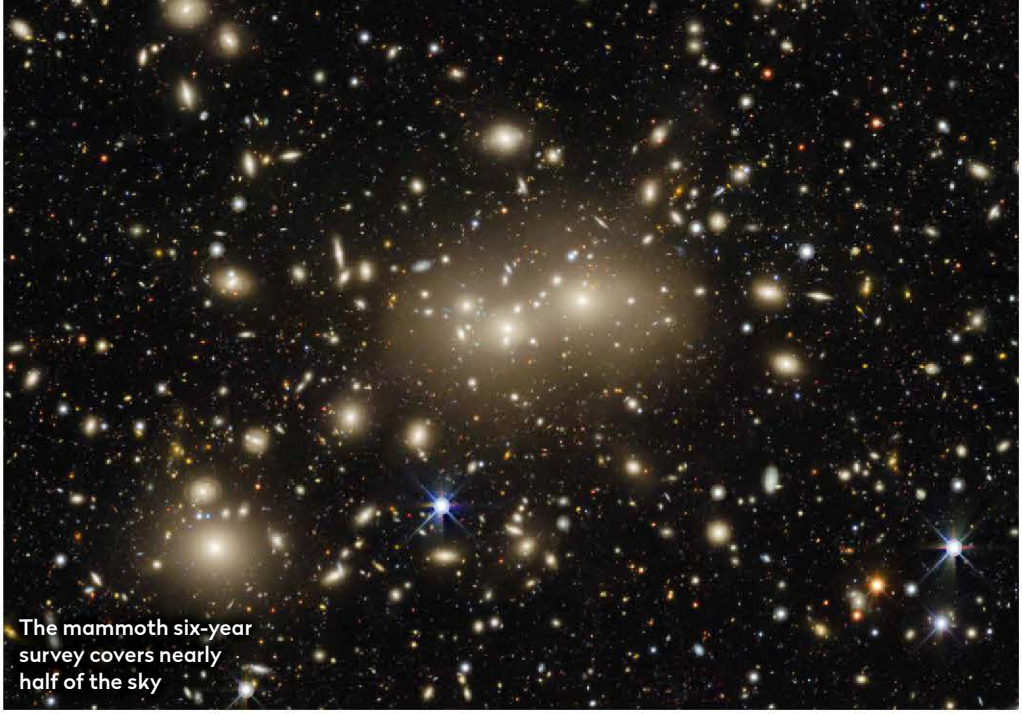


The mammoth six-year survey covers nearly half of the sky

Billion-galaxy map now even bigger

The sky chart for cosmology will help many other space fields too

The largest 2D map of the sky ever produced has grown even larger, after the 10th data release of the DESI Legacy Imaging Survey expanded its view to more than 20,000 square degrees, almost half the sky, and introduced additional wavelength coverage.

The survey mapped the location of over one billion galaxies, with the hope of better understanding dark energy and dark matter. The new release – which is available to anyone who wants access – includes infrared information to calculate the redshift of distant galaxies. The additions make the map useful to a much wider range of astronomers.

"It is this ease of access which has made this survey so impactful," says Arjun Dey at NOIRLab, the organisation that operates several of the telescopes involved with the survey. "We hope that in a few years, the Legacy Surveys will have the most complete map of the entire sky and provide a treasure trove for scientists well into the future." **noirlab.edu**

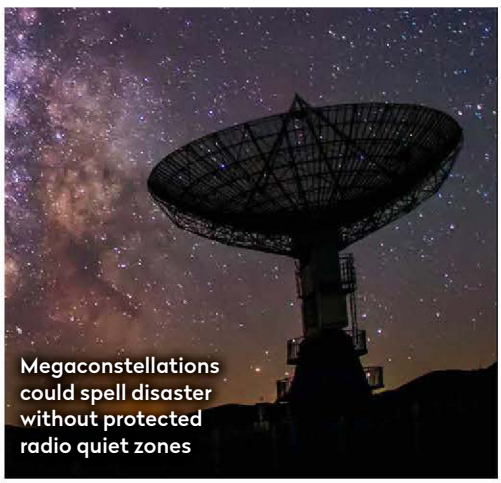
Radio astronomy needs satellites protection

A new paper from a group of astronomers and engineers has suggested creating Radio Dynamic Zones, where organisations could test out their radio transmitting equipment to see how it might affect astronomical observations.

While there are protections around radio telescope facilities to create 'radio quiet zones', these do not extend to orbit, and the advent of megaconstellations – networks of thousands of satellites providing global telecommunications and internet connectivity – has vastly increased the number of satellites being launched.

SpaceX's broadband internet network, Starlink, already has thousands of satellites in orbit, and in March UK-based OneWeb launched the final batch of its 618-satellite network. Amazon has also announced it will move ahead with its own Project Kuiper broadband network of 3,200 satellites, starting the launch phase in early 2024. These networks, by design, cover the entire globe, meaning no area on Earth would be free from their interference.

To remedy this, the paper proposes creating special zones which have the same protections from outside radio transmissions as quiet zones, but would be outfitted with monitors. Astronomers, satellite manufacturers and other technology developers could then use the areas to test their receivers and transmitters at large scales, ensuring they do not unknowingly encroach on astronomical observations. **cps.iau.org**



Megaconstellations could spell disaster without protected radio quiet zones

NEWS IN BRIEF

Ocean currents spin Europa

Currents in the ocean on Jupiter's moon Europa could be pushing its free-floating icy shell, changing its rotation rate over time, according to a new set of computer simulations. The drag between the ocean and the icy shell could also be responsible for some of the cracks and ridges seen on the moon's surface.

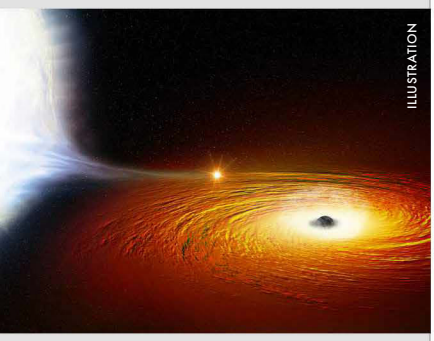
Leicester steps up for space

Space City Leicester has become one of the largest enterprise zones for space-related activities in the UK. The newly expanded cluster of facilities includes the National Space Centre and will be home to research, production, manufacture and development.

Brian May knighted

Queen guitarist Brian May received a knighthood from King Charles for his services to music and charity on 15 March. As well as his musical success, May has had a lifelong interest in space science, appearing on multiple episodes of *The Sky at Night* and *Stargazing Live*. In 2007 he completed his PhD on zodiacal dust bands, 37 years after he started.

NEWS IN BRIEF



ILLUSTRATION

Baby star near black hole

It shouldn't exist, but recent observations have uncovered a baby star, X3a, orbiting close to Sagittarius A*, the black hole at the centre of our Galaxy. Intense radiation near Sgr A* should prevent stars forming, yet X3a is only a few tens of thousands of years old. Astronomers believe it formed in a dust cloud orbiting the black hole.

ExoMars in 2028

ESA's Rosalind Franklin rover may still make it to Mars. Its ExoMars mission was originally meant to launch in 2022 on a Russian rocket but was put on hiatus following Russia's invasion of Ukraine. ESA says it is now working with international partners to reshape the mission, with a target launch date of 2028.

Virgin Orbit halts work

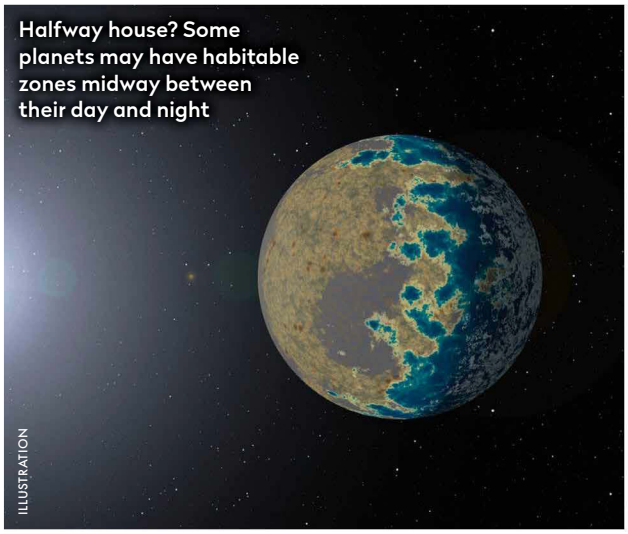
Small-sat launch company Virgin Orbit was forced to suspend operations on 16 March following the failure of its launch attempt from Spaceport Cornwall in January. As of writing, the company was close to securing $200m from a venture capital investor which would allow it to resume operations.

NASA/CXC/M.WEISS, NASA JPL/CALTECH, ALMA (ESO/NAOJ/NRAO)/IZZO ET AL

BULLETIN

Life could exist on locked planets

A ring of temperate climate may offer a habitable haven


Halfway house? Some planets may have habitable zones midway between their day and night

ILLUSTRATION

Extra-terrestrial life could find a haven in an unexpected place – the narrow band between day and night on planets where one side is tidally locked facing their star.

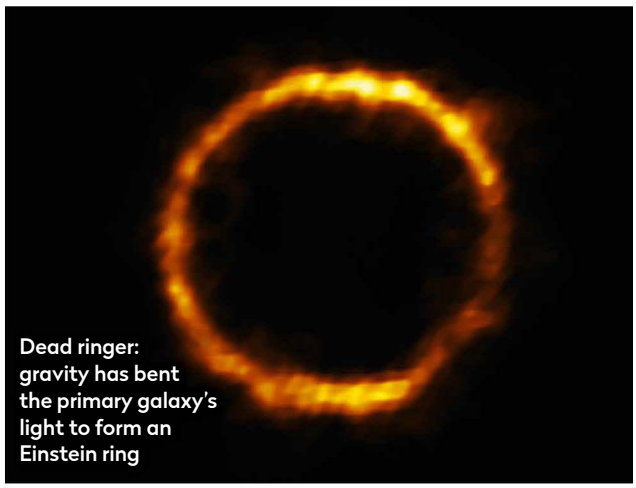
"This is a planet where the dayside can be scorching hot, well beyond habitability, and the night side is going to be freezing, potentially covered in ice. You could have large glaciers on the night side," says Ana Lobo from the University of California, Irvine.

Such worlds have been found around many M-dwarf stars, which make up 70 per cent of the stars in the night sky. To see if these common worlds could be habitable, Lobo used computer simulations to reveal that the light–dark boundary region (ironically known as the Terminator Zone) can have temperatures in the 'sweet spot' where water can remain liquid. Liquid water is a key component of life on Earth, so its presence is considered a vital marker of potential habitability. **www.uci.edu**

Early galaxies have seen many stars

A pair of galaxies from the early Universe are far more evolved than their age would suggest, according to new images from James Webb Space Telescope (JWST).

The primary galaxy, SPT0418-SE, is so distant we are seeing it as it was just 1.4 billion years after the Big Bang. Its light has been gravitationally lensed (bent by a foreground object), making it appear as a near-perfect ring called an Einstein ring. While observing the galaxy with the JWST, a team of astronomers discovered that it has a companion galaxy located just 16,000 lightyears away.


Dead ringer: gravity has bent the primary galaxy's light to form an Einstein ring

Spectral data revealed that both galaxies are rich in 'metals'. In an astronomical context this means anything heavier than helium – elements that are only formed inside stars and then seeded into space when the star dies.

"We are seeing the leftovers of at least a couple of generations of stars having lived and died within the first billion years of the Universe's existence, which is not what we typically see," says Amit Vishwas from Cornell University, who took part in the study. "We speculate that the process of forming stars in these galaxies must have been very efficient and started very early in the Universe." **www.cornell.edu**

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Our experts examine the hottest new research

CUTTING EDGE

DART was bang on target

The asteroid-deflecting DART mission worked with incredible accuracy

NASA/ESA/STSCI AND JIAN-YANG LI (PSI) IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI), NASA/CXC/M.WEISS

▲ **Dust and chunks stream from the now-rerouted moon Dimorphos in the hours and days after the impact**

Although no *known* asteroid poses a threat to Earth for at least the next century, the database we've built up of near-Earth asteroids is not yet complete for smaller bodies that could still cause devastation on a regional scale.

Several methods have been proposed to protect Earth from asteroids on a collision course, including blowing them up with a nuclear weapon and using a 'gravity tractor', a large spacecraft whose gravity pulls the asteroid so it misses our planet. The strategy identified as the highest priority to develop and test, however, is kinetic impact. In simple terms: fly a spacecraft at high speed into the asteroid so that it is nudged onto a different trajectory.

NASA's DART (Double Asteroid Redirection Test) mission was developed to demonstrate just this approach. Launched in November 2021, DART successfully impacted Dimorphos, the 160m moon of 800m asteroid Didymos, at just over 22,000km/h at 23:14 UTC on 26 September 2022.

A number of research papers have described what this milestone space mission taught us. Here I'm focusing on a report led by Terik Daly, Carolyn Ernst and Olivier Barnouin, all at Johns Hopkins University Applied Physics Laboratory, which pieces together the details of the impact itself with astonishing precision.

DART continuously beamed back images from its onboard camera during the approach. The final full image, taken just under two seconds before impact, shows a boulder-strewn landscape, with a pixel resolution of just 5cm. DART impacted in the direction opposite the asteroid's motion, almost straight down into the asteroid's surface, at an angle of around 73°. By analysing the images, the team determined the precise point that DART hit to an accuracy of better than 70cm. The impact site was within 25m of the equator of Dimorphos: like striking a snooker ball with the cue, the perfect spot to hit to impart the maximum momentum (without 'wasting' any of the impact energy in causing the target body to spin). The final image even allowed the team to model the precise nature of the impact. Two large boulders can be seen in the centre of the photo, and the team describe how the leading edge of the spacecraft's left-hand solar panel must have struck one of the boulders; almost immediately afterwards, the right-hand solar panel grazed the other boulder, and 0.3 milliseconds later the main body of the spacecraft slammed into the surface between the two.

"The impact site was within 25m of the equator: like striking a snooker ball with the cue, the perfect spot to hit"

For the final four hours before impact, DART's autonomous manoeuvring system controlled the spacecraft's trajectory to target it directly into the middle of Dimorphos, and this technology proved itself admirably. The success demonstrates that a spacecraft like DART would be able to deflect an asteroid on a collision course with Earth, without needing a precursor reconnaissance mission. The impactor could be launched directly to the target itself. We can breathe a little easier for knowing that should a deadly asteroid be discovered, we've demonstrated that a kinetic impactor could protect Earth from the threat.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Successful Kinetic Impact into an Asteroid for Planetary Defense* by R Terik Daly et al
Read it online at: arxiv.org/abs/2303.02248

Blowing bubbles in the early Universe

Do infant galaxies work together to clear the hydrogen around them?

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Much of the excitement about early JWST observations has come from finding the most distant galaxies, which we see as they were just a few hundred million years after the Big Bang. What's now becoming clear is that there are remarkable systems all over the early Universe, and none more so than galaxy JADES-GS-z7-LA, the subject of this month's paper.

In images, the galaxy is not much more than a faint splodge a few pixels across, but JWST spectra of this faint source tell us that it's a galaxy at a redshift of 7.3. That means that we're seeing a system just 729 million years after the Big Bang. What's even more impressive is that, through careful analysis of that spectrum, we can say something about what this thing was actually like.

It is a galactic minnow, only a hundredth of the mass of the Large Magellanic Cloud. Despite its youth, it has already formed stars, half of which seem to have formed recently in a period of star formation that lasted only a couple of million years. It's still producing more stars, at a rate that approaches that achieved by the Milky Way, even though our Galaxy is a thousand times more massive.

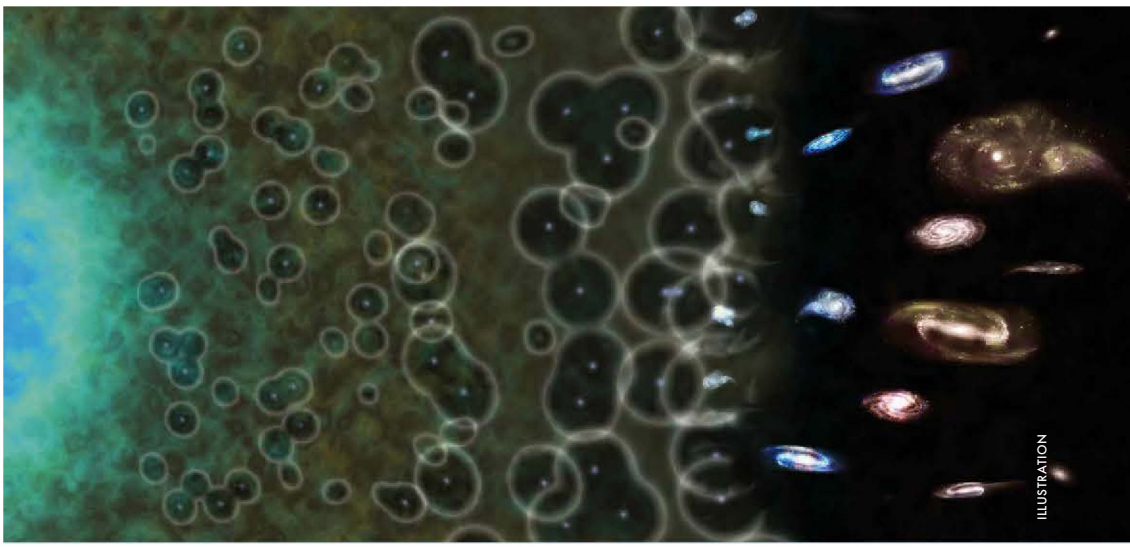
The Universe in which this small galaxy finds itself must be very different from our own. Back then, the Universe was still lighting up, emerging from its early dark ages. In the dark, the gas between the galaxies will be in the form of hydrogen molecules consisting of two atoms bound together. Today, in the bright glare of the present-day Universe, such molecules will be broken up by starlight into two individual hydrogen atoms.

> ***"If there are enough small galaxies, these bubbles will have begun to overlap, allowing us to see through them clearly"***

Understanding how this transition, which cosmologists confusingly call reionisation, happened is an important goal for JWST. Until now, we've only been able to look at the biggest and brightest galaxies, but many suspect the collective contribution of light from many smaller systems – like JADES-GS-z7-LA – might be more important.

The spectrum of JADES-GS-z7-LA shows a bright line that seems to come from hydrogen molecules in the galaxy. That's a bit confusing, as this light should be absorbed by the individual neutral hydrogen atoms around the galaxy before it reaches us. One possibility is that ultraviolet light from young stars in the galaxy itself could have cleared a bubble in the molecular hydrogen around it, but not enough stars have formed to clear a space big enough to produce a signal of the observed strength. A nearby companion, which seems to be at the same distance, isn't big enough to help.

So what's happening? One possibility is that we've found a crowded neighbourhood, home to many small galaxies like JADES-GS-z7-LA. Each of these will have blown its own little bubble, and if there are enough of them these bubbles will have begun to overlap, allowing us to see through them clearly. This region is right on the cusp of that transition from a neutral to an ionised Universe – and JADES-GS-z7-LA and its fellow tiny galaxies clearly have an outsized role to play in this most important event.



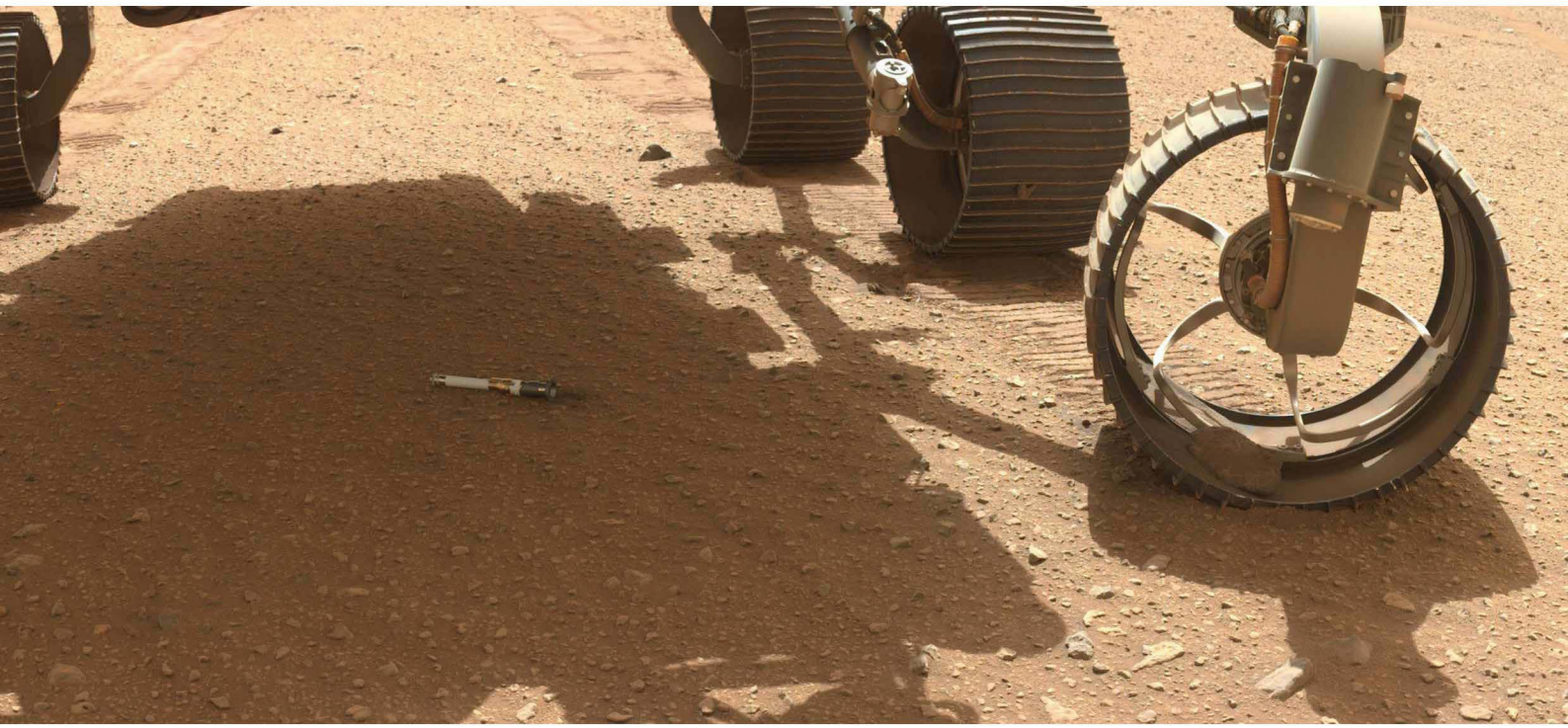
ILLUSTRATION

▼ **Small post-Big Bang (left) galaxies might team up to blow away the fog of hydrogen**

Chris Lintott was reading... *JADES: Discovery of Extremely High Equivalent Width Lyman-alpha Emission from a Faint Galaxy within an Ionized Bubble at z=7.3.* **Read it online at: arxiv.org/abs/2302.12805**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



▲ **Perseverance drops a sample tube filled with igneous rock for collection by a future mission**

In April's *Sky at Night*, chemist **Mark Sephton** revealed how we'll look for signs of Martian life in samples collected by Perseverance

The search for life beyond Earth is entering an exciting period. Traditionally, we've investigated our planetary neighbour Mars with landers and rovers that examine the landscape using their onboard instruments. This 'in-situ' approach essentially delivers a restricted collection of instrumentation to a place where it has access to a large amount of sample material.

Now, though, the search for life on Mars is entering a time of sample return. This inverts the traditional in-situ approach, by taking a restricted amount of sample – in the case of Mars Sample Return, about half a kilogram – and bringing it to Earth where it can be analysed by an entire world's worth of highly specified laboratories. Moreover, laboratory methods are constantly improving; the samples are expected to arrive in the next decade, and the 2030s should be a time of unprecedented analytical capability.

The first leg of Mars Sample Return is currently underway. The Mars 2020 mission and its Perseverance rover is collecting rock, soil and gas samples in Jezero Crater, a 45km-wide impact structure in the Nili Fossae region. Jezero Crater was chosen as a landing site because it contains a delta or fan which we believe suggests that flowing water filled the structure to form a crater lake. Using its suite of scientific instruments, Perseverance is able to identify materials in the landscape around it, looking for those which may be of interest for the scientific community.

On Earth, all known biochemistry relies on liquid water, so the presence of a lake indicates a potentially habitable environment. It's possible that sediments deposited in the lake could preserve signals of this past life, if it existed. Here on Earth, sediments associated with deltas are prodigious preservers of life's organic remains and we hope this has, at least in part, been replicated on Mars.

Message in a bottle

The rocks which may contain evidence of past life are probably very old. Compared to Earth, the Red Planet lost its magnetic field and atmosphere relatively quickly, and without their protective and warming roles, Mars's habitability would decrease over time. Old rocks present some challenges because the longer materials are stored within them, the higher the likelihood that something would happen to them, causing them to degrade. It could be that the primary

Mark Sephton is a professor of organic chemistry and sample return scientist on the Mars 2020 science team

signals of life, though once present, have long since been lost. For this reason, it will be more important than ever to choose the best samples to return.

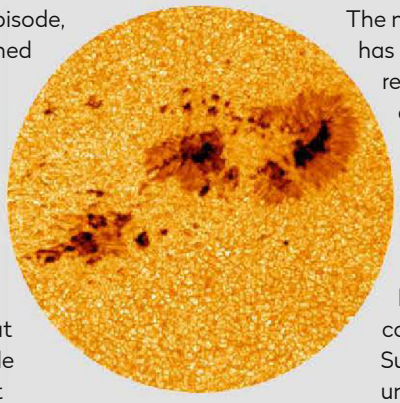
If organic matter has managed to survive in the samples, astrobiologists will be able to begin a forensic analysis on them that they could never do with Perseverance's limited suite of instruments. Analytical instruments such as mass spectrometers – which can pick out a vast array of elements and chemicals – can interrogate these samples, looking for evidence of past life. Terrestrial life uses specific organic compounds which allow its biochemistry to operate. If such compounds are well-preserved, they would provide a detailed architecture of life's organic remains that's distinguishable from any non-biological counterparts. Hopefully, we'll be able to obtain a great amount of interpretative detail and reveal organic markers of life that will tell us both about the parent organism and the environment in which it lived.

With ongoing activities on Mars and the prospect of sample return, there are intense preparations being made back on Earth. Researchers are being trained and techniques are being optimised. When the Mars samples are brought back, the terrestrial scientific community will be ready and waiting.

Looking back: The Sky at Night

18 May 1977

On the 18 May 1977 episode, Patrick Moore was joined by solar scientist Ron Maddison to discuss the ongoing solar cycle. Our Sun goes through a cycle of increasing and decreasing solar activity spanning roughly 11 years, and at the time of the episode Solar Cycle 21 was just getting under way.



▲ **Sunspot numbers show us if activity is hotting up on the Sun**

Solar cycles are normally tracked via the number of sunspots visible on the surface, and in 1977 they were being slow to rise. Given that the previous cycle had experienced extremely low activity, it was thought the same might happen again. However, shortly after the episode aired, sunspot numbers began to rise and the cycle had its most active month in November 1979 – just two years after it began.

The number of sunspots has been measured regularly since the 18th century, though sporadic records exist from earlier times. In the decade leading up to the episode, new satellites were being launched to constantly observe the Sun, beginning an unbroken era of space monitoring that continues to this day.

These observations clearly show that some solar maximums are more active than others. These active years appear to follow their own cycle, over roughly a century. And yet while decades of monitoring allows us to make predictions, the Sun sometimes throws a curve ball. Our current cycle, 25, has surprised solar scientists by being much stronger than expected. It seems we still have much to learn about our star.

Will an asteroid destroy Earth?

How real is the threat of an asteroid impact on Earth? In this episode, Maggie learns how near-Earth asteroids are monitored, while Chris discovers more about the recent DART mission that smashed into an asteroid to change its orbit. Plus, news about the Winchcombe meteorite that suggests asteroids might bring life, as well as destruction, to Earth.

BBC Four, **10 May,** 10pm (first repeat will be on BBC Four, **18 May**, 7pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information

▲ **How seriously should we take the threat of an asteroid impacting our home planet?**

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: two Philip's titles

The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2023* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

One small step...

I bought my seven-year-old granddaughter a Celestron StarSense LT 70AZ telescope for Christmas and since then she and I have become more and more excited about our view of the night sky. We ordered a Svbony SV105 camera in March to capture some images of the night sky. Despite the fact that it was cloudy, the night after it arrived we still managed our first astrophotography of the Moon, captured untracked from the back garden.

We started processing with SharpCap, using its automatic exposure settings to record 100 frames as set by its Quick Capture menu. Then we imported the video into AutoStakkert! to split it into individual frames. Next we selected one of the good-quality frames and loaded it into RegiStax, where we made the craters stand out a little more by adjusting the image's brightness and contrast with its default Wavelet filter. It was thanks to your magazine and Martin Lewis's article in the March 2023 issue ('Processing: Bringing out the shadow profile of Plato's east rim', page 78), that we learned of the existence of AutoStakkert! and RegiStax. Although not of the clarity of some of the images in your magazine, we thought it might still be of interest to show what can be done by first-time astrophotographers on a limited budget.

Niamh Robertson (aged 7) and Roy Chisem (aged 66), Ulverston, Cumbria

▲ **Lunar explorers Niamh and granddad Roy captured this in a cracking first stab at imaging**

Congratulations on your first image of the Moon, Niamh! Good luck to you and your grandfather on your astrophotography journey. **– *Ed.***

Tweet

Anthony Grice
@Spadge27544 • 13 March
Mars, Orion and the Pleiades from the Falklands skies @skyatnightmag

Knut's shot of the Lights at the end of the wingtip

Flying high

My wife and I were on a Northern Lights flight from Gatwick on 13 March which was hosted by Pete Lawrence. He gave a great pre-flight presentation and we loved his commentary during the flight. We got an amazing view of the night sky without light pollution from the blacked-out aircraft cabin. It wasn't predicted to be a great night for viewing the aurora but, thanks to Pete's pre-flight advice on camera settings and a bit of luck, I managed a half-decent hand-held image with my Nikon D750 DSLR camera. With a bit of post-processing to increase exposure and vibrance, my first Northern Lights experience has been captured. I think I'm hooked!

Knut Beekmann, Weston-in-Gordano, North Somerset

In at the deep end

This is my first proper attempt at a deep-sky image, taken from Wembury Beach car park in South Devon in February with my Canon EOS 800D DSLR camera and Samyang 135mm f/2.0 lens on a Sky-Watcher Star Adventurer 2i mount. I know there is considerable work and learning still to do on both my data acquisition and processing skills. I'm sure

▲ **Our how-tos inspired Steve to get this lovely widefield view of the Rosette Nebula**

there are many faults with the image; it's my first-ever attempt at blending two photos together using Starnet++ to remove stars in the image and Affinity Photo for stacking and image adjustments. But sometimes it's helpful for beginners to see how other beginners are faring on their individual journeys; reassurance that others too are making and learning from the same mistakes.

I've never used stacking or photo-editing software, but your magazine keeps me motivated. Thank you for all your encouraging and informative articles in the magazine and online. Hopefully, this time next year I will be able to show far better progress. Astronomy, astrophotography and photo editing are such exciting and thrilling new learning journeys to be on!

Steve Parke, via email

Moore laughs

I was very pleased that your March edition included a commemorative article on Sir Patrick Moore. It was excellent in the way it presented his life and character, in particular his dedication to astronomy, his generosity and his sense of humour. On the latter quality, I enjoyed being reminded of his brief (incognito) membership of the Flat Earth Society; it was indeed a joke, but one with a serious side. The International Flat Earth Research Society, to give it its full name, had as its motto "To observe, think freely, rediscover forgotten facts and oppose theoretical dogmatic assumptions". Its British branch was run by an elderly craftsman sign-painter by the name of Sam Shenton, who lived in Dover. I met Mr Shenton on a few occasions and invited him to give a lecture to some students of mine in Canterbury. They listened politely, but I don't ▶

ON FACEBOOK

As we celebrated Patrick Moore's 100th birthday, many of you got in touch to share your memories.

Peter Vines I met Patrick several times. He had a great sense of humour – unlike his serious TV persona. A great man who did much to further the cause of astronomy.

Heidi Cooper Wonderful man!

Chris Coyne My granddad loved the show and got me into it. I showed Patrick my granddad's letters with hand-drawn pictures of space-related facts, which he thought were great and loved getting kids interested in astronomy.

Anthony James Bean Followed his programmes from when I was 7 years old. Now I'm 67 and that fascination is still with me. I've learned a lot and it's all thanks to Patrick.

Richard Dorset Always replied to letters. But you had to remember what questions you'd asked, as his answers were short, eg 1. Yes. 2. Quite possibly. 3. No.

Chris Bailey Played in his garden in the '60s. My father used to visit him to discuss his Moon drawings. I remember he had dandelion and burdock fizzy drink, the only time I ever drank it.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I want to upgrade my kit to create an imaging setup using my DSLR camera for the deep sky and also planets. Would I be better off getting a larger-aperture refractor or a smaller-aperture refractor with ED/apo-quality lenses?

FERGUS BROWN

▲ **Small refractors like William Optics RedCat 51 offer a no-fuss route to astrophotography**

Deep-sky and planetary imaging require very different instruments, so unfortunately there is no solution that suits both requirements well. A DSLR camera is much better suited to deep sky, so we'll start there.

Astrophotography shows up any deficiencies in your optics, so concentrate on buying the best-quality optics you can afford. It would be better to buy a smaller apochromatic refractor, giving you a wider field of view and placing fewer demands on the weight and tracking ability of your mount. However, you should also factor in the cost of a field flattener, unless you buy a Petzval refractor.

With astrophotography, aperture is of much less importance than it is for observing, and wonderful results can be achieved with apertures as small as 50mm. Have a look online for what can be achieved with refractors such as a William Optics RedCat 51, Sky-Watcher Evostar 80ED DS-Pro or a StellaMira 80mm ED for example.

Steve's top tip

What are dovetail bars for?

Most telescopes are supplied with a profiled mounting bar attached either directly to the base of the telescope or to the scope's tube rings. These bars have angled edges which, when viewed end-on, look like a 'dovetail'. Most mounts are equipped with a special clamp for attaching the telescope using either a single bolt or a moving side-piece similar to a vice, and these have internal angled edges that match the profile of the dovetail bar. This simple arrangement makes for quick, secure attachment and removal of the telescope from the mount and allows adjustments to be made for balance.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

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▶ think there were many converts. Afterwards over tea, Sam told me, with evident pride, that he had recently been made a fellow of the Royal Astronomical Society. What he didn't know was that it was Patrick who had proposed him for this honour. Of course, Patrick always enjoyed meeting a true eccentric, but he also recognised another upholder of those two virtues of the Enlightenment of which Patrick was an admirable champion: the determination to think for oneself and the ability to show toleration of the different opinions of others.
Hamish Halls, Liskeard, Cornwall
▶ Turn to page 72 to find out how we know Earth isn't flat.

On the run

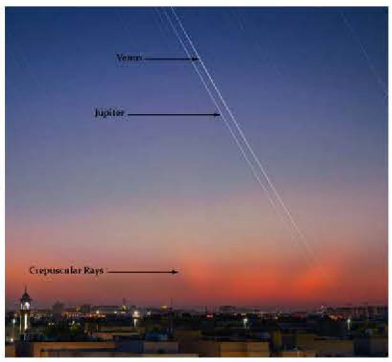
This is NGC 1977, the Running Man Nebula (right), usually seen as 'an extra' when imaging the Orion Nebula, or just cut off the image altogether. I have rarely seen it as a separate feature and thought this object deserved to have its own chance to be centre stage for a change. It is a beautiful subject, with the bright stars showing off the nebulosity around it, giving it a slightly blue hue and lighting up the Running Man. I used an unfiltered, modified Canon EOS 1100D DSLR camera on my 6-inch Sky-Watcher Explorer, mounted on an HEQ5 Pro mount, taking 39 exposures of 2 minutes each, together with 16 dark and bias frames. All this from the comfort of my back garden even with the light pollution that, sadly, goes with it!
Sue Silver, Sheffield

Sue's pic of Orion's athletic companion.

Instagram

_amaar_amir • 5 March

Trails of Jupiter and Venus, featuring Uranus and crepuscular rays @bbcskyatnightmag @cosmograg @astrobiasky



SOCIETY IN FOCUS

Northern Ireland Amateur Astronomy Society (NIAAS) was founded in 1997 by two local enthusiasts. Known as East Antrim Astronomical Society until 2009, our group had humble beginnings. Meetings were held in a local primary school. After a few years of sitting on children's chairs, it was decided to seek new premises and the society moved to its present location at the High School in Ballyclare, about 20km from Belfast.

The membership now is spread quite far and wide across Northern Ireland and our magazine *Azimuth* contains articles by members of the society.

Today NIAAS has around 50 regular members and holds meetings on the first Monday of each month from September to May. Many speakers are local, mainly from Queens University Belfast and Armagh Observatory, but occasionally from further afield.

▲ A new stargazing spot for NIAAS, OM Dark Sky Park in Davagh, County Tyrone

We're an enthusiastic group with a wide range of equipment and have recently visited the dark-sky site at Davagh in County Tyrone. We have been known to travel much further in search of dark skies, usually to the west coast of Ireland where we regularly attend the annual Skellig Star Party at the International Dark Sky Reserve in County Kerry.
Stevie Beasant, NIAAS Secretary
▶ niaas.co.uk

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

Little Astronomers morning

Armagh Planetarium, 26 May, 10am

In this under-5s dome show, budding astronomers can join astronaut George as he explores the Solar System, then head to the sensory room for toddler activities and exhibits. Children £5, accompanying adults free. **armagh.space/planetarium/whats-on**

Libby Jackson talk

Montpelier, Bristol, and online, 12 May, 7pm

In this talk for Bristol Astronomical Society, Libby Jackson, head of space exploration for the UK Space Agency, discusses the UK's plans for going to the Moon. £3 for non-members. **bristolastrosoc.org.uk/all-events**

Stonehenge and Astronomy

Shurdington, Cheltenham, 13 May, 7:30pm

Stonehenge tour guide Simon Banton gives a talk for Cotswold Astronomical Society about the site's astronomical associations, followed by refreshments and a discussion on observing the night sky in May. £2 for non-members. **cotswoldas.org.uk/our-events**

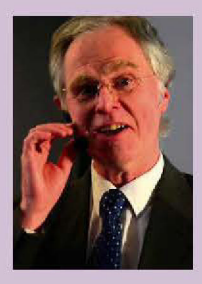
The Summer Sky

Swinton Bottom Club, Rotherham, and online, 18 May, 7:45pm

Join Mexborough & Swinton Astronomical Society to discover all there is to see in the night sky over the next few months, whether viewing through binoculars, telescope or naked eye. £2 for non-members. **msas.org.uk/about/programme**

ARMAGH PLANETARIUM, PROF. MARK BIRKINSHAW/YOUTUBE, DR ANA DUARTE CABRAL

PICK OF THE MONTH



▲ The National Museum in the centre of Cardiff hosts the BAA's meet-up on all things galactic, including talks from Mark Birkinshaw (top) and Ana Duarte Cabral (bottom)

Cosmology: Galaxies and Stars

National Museum Cardiff, 13 May, 10am

How is a galaxy made? What happens when a star dies? And what *is* a supermassive black hole? For this year's spring meeting, the British Astronomical Association will host a panel of experts, including Professor Mark Birkinshaw of the University of Bristol and Dr Ana Duarte Cabral of Cardiff University, for a full day of astrophysics, answering these cosmological questions and more. Anyone with an interest in astronomy or cosmology is welcome to come along, though the event is likely to be a little too in-depth for younger astronomers. Children £8, adults £12. **britastro.org/event/baa-spring-meeting**

Indigenous Australian Astronomy

Online, 19 May, 7:30pm

Aboriginal Australians are widely thought of as the first astronomers. In this talk, Dr Pete Kuzma shares stories of Australia's first peoples and their beliefs about the night sky. Free to watch. **astronomyedinburgh.org/events**

Starting from Scratch Astrophotography Day

Humfrey Rooms, Northampton, 21 May, 11am

This one-day course covers everything a beginner needs to know to photograph the night sky, from setting up a tripod to image processing. £12 for non-members. **popastro.com**

13 Things to Improve your Lunar/Planetary Images

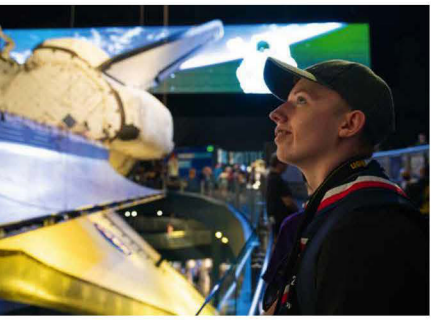
Standalone Farm, Letchworth, 31 May, 7:30 pm

A Letchworth & District Astronomical Society talk by Astronomy Photographer of the Year prizewinner Martin Lewis. £3 for non-members. **ldas.org.uk/events/list**

FIELD OF VIEW

The trip of my dreams

Scout **Simon Shemetilo** won a VIP visit to a rocket launch from Cape Canaveral



▲ **Left to right: Absorbing space history at the Kennedy Space Center. Simon got to meet the behind-the-scenes launch team before watching Inmarsat's largest satellite take off on board a SpaceX rocket**

16-year-old **Simon Shemetilo** from Tower Hamlets joined the Scouts as a Cub Scout. His winning entry researched how future satellites could perform data storage in space

At 22:59 EST on 17 February 2023, I was fortunate enough to be at Cape Canaveral to witness the launch of the Inmarsat I-6 F2 communications satellite. I'd won a competition run by Inmarsat for the Scouts and my entry was selected by British astronaut Tim Peake!

My entry was all about how space can help reduce global warming on planet Earth. Being a Scout has really helped me to appreciate the environment we live in and what's beyond it, through developing my skills with activities like the Astronautics activity badge and the Community Impact badge.

This was the trip of my dreams because it's the area I am most passionate about. Space and the developments within it have had a big impact on me, inspiring me to pursue a career in the aerospace industry. The trip gave me the opportunity to take a closer look into the path I want to take and we got the full VIP experience. I was able to talk to the team that made the satellite launch possible, and learn about all the challenges they had to overcome to get the satellite into space.

Waiting for the flight to Florida I couldn't believe that this trip was a reality. I was so excited as we walked around Kennedy Space Center, seeing the historic exhibitions first-hand. One of the best parts was being able to see the Falcon 9 rocket standing on the launch pad ready for take-off. We must have been only 100 metres away, but seeing a rocket in person is completely different to seeing it in a movie – it is colossal!

Before the launch, we were given a presentation by Inmarsat and SpaceX where they explained how the satellite would be carried up and what its function would be for the next 15 years, as well as the flight plan of how the rocket would take off and deliver the satellite into orbit. For me this was brilliant; the most intriguing presentation I have ever seen.

But of course, the part I was most looking forward to was seeing the actual launch. We got to view it from the balcony of a building directly next to NASA's massive Vehicle Assembly Building. The launch pad itself was isolated off in the distance and the night was pitch black while we waited for the countdown.

We were apprehensive as the final 10 seconds of the countdown came over the loudspeakers from mission control, and then the engines ignited and lit up the whole sky. It was completely awe-inspiring and all we could do was watch on in silence. About 10 seconds after lift-off, a thundering sound developed from the direction of the launch pad and grew steadily louder, until the entire building started shaking. That gave me an appreciation for the rocket's true power. It was phenomenal!

It was truly an unforgettable experience that will stay with me for a lifetime.

RALPH HEWITT X4, INMARSAT/SPACEX

BBC

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BBC Sky at Night MAGAZINE

Capturing THE MAGNIFICENT Milky Way

Get ready for the return of late summer nights under the stars as **Will Gater** presents a beginners' guide to photographing our ever-changing home Galaxy

Whether you've got basic kit or full bells-and-whistles tracking gear, we'll help you get great images of our glorious Galaxy

As the lighter nights begin to swing around in May, one thing I like to do is fire up Stellarium and plan out all the things I want to photograph when proper darkness returns in the late summer. Almost always, the target that occupies me the most, no matter how many times I've imaged it, is the Milky Way. Widefield, nightscape or long-focal-length close-up – it doesn't matter what format we're talking about, there's always something our Galaxy can offer.

It's important to think ahead when it comes to Milky Way imaging. The view changes from month to month, week to week and even hour to hour throughout the night. And the best time to photograph our Galaxy from the UK, in my opinion, is the first weeks of August. Not only has astronomical darkness come back for most of us in the UK by that point, but you also don't have to wait all night for the band of the Milky Way to be positioned close to the meridian. Plus, from a composition perspective I love how the core of the Galaxy and the swathe of its spiral arms, arcing up into the eastern sky, are positioned as midnight approaches.

If you've never dipped your toes into the waters of Milky Way astrophotography, now's the perfect time to get prepped for this season. So read on as we introduce you to shooting the spectacular celestial metropolis that we all call home. ▶

@THESHED_PHOTOSTUDIO, WILL GATER

Use the right kit

You can achieve spectacular images even with a fairly modest setup

One of the really nice things about photographing the Milky Way is that there are lots of ways to do it, with lots of different types, and levels, of equipment. This means it's one of those targets that you can start off imaging as a beginner and keep coming back to year after year as you get more experience, often finding new and different ways of doing things as you do.

The remarkable recent advances in smartphone camera tech mean it's now possible to get fantastic widefield images of the Milky Way using some of the high-end models equipped with low-light imaging modes. For many new astrophotographers, another common entry point into imaging is with something like an off-the-shelf DSLR or bridge camera with a stock wide-angle lens. This kind of kit, combined with a normal photographic tripod, is a brilliant way to start capturing basic portraits of the Milky Way, particularly if the lens is fast – that is, if the f-ratio it can achieve when the lens aperture is set wide open is relatively low, say in the region of f/2–3 or thereabouts. A 30-second exposure using a medium-to-high ISO setting – let's say 1600 to 6400 – with such a setup will easily bring out great detail in the rich star fields and silhouetted dust lanes of the Milky Way from a dark site.

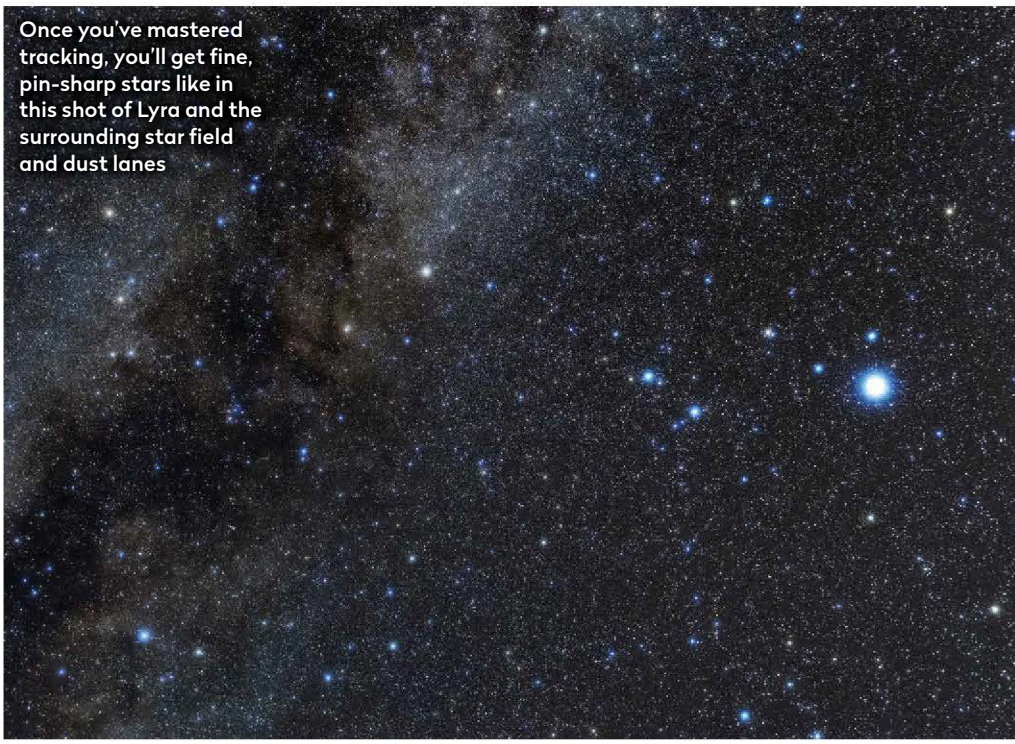
▲ Pocket pro: got a high-end smartphone with low-light settings? Just add a mount and beautiful Milky Way shots can be yours

Beyond widefield Milky Way nightscapes, though, the challenge with shooting with a static tripod is that if you want to use a longer exposure – to go deeper and capture more, faint, details – you run into the problem of the sky rotating and stars trailing. Now, you can get around this by taking your shorter exposures and stacking them in software to improve the signal-to-noise ratio (and then doing some clever compositing using layer masks, if you're shooting with a landscape in the frame). But the other approach is to progress to mounting or piggybacking your camera on a driven telescope mount or a smaller, portable tracking mount.

Track for longer shots

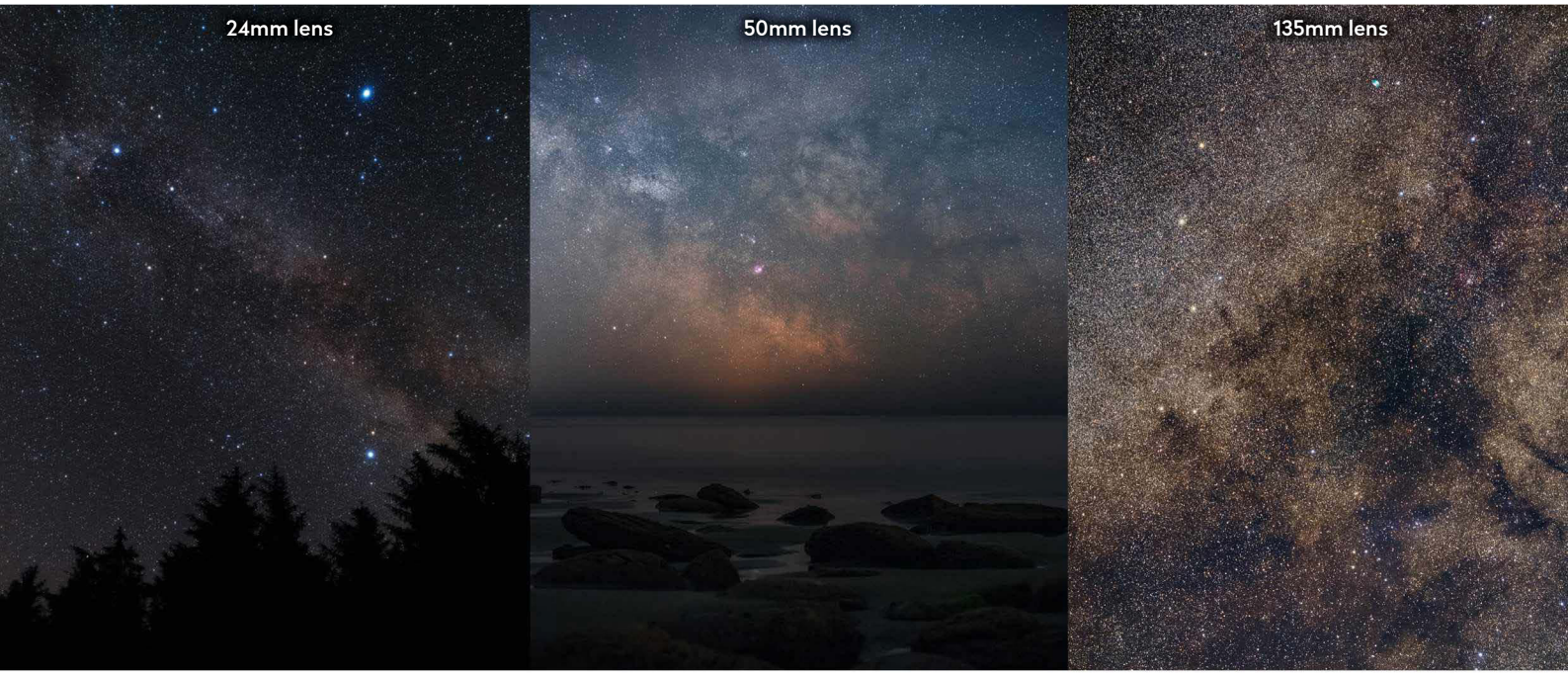
This allows you to do two things: first, it enables you to drop down to a slightly lower ISO setting while dialling up the exposure length, so any resultant single image is less noisy – particularly useful for nightscapes. And, secondly, it opens up those much longer exposures more generally – we're talking several minutes at a time here – because now the mount is cancelling out Earth's rotation and keeping the stars point-like; with this, you can then take multiple long-exposure sub-frames and stack them together to create detail-rich, deep, widefields of the

Even better, a DSLR on a tracking mount will allow longer shots that avoid star trailing



Once you've mastered tracking, you'll get fine, pin-sharp stars like in this shot of Lyra and the surrounding star field and dust lanes

WILL GATER X 2, INDYSYSTEM/ISTOCK/GETTY IMAGES, M-GUCCI/ISTOCK/GETTY IMAGES, SKY SAFARI, STELLARIUM



▲ **The Milky Way captured at three different focal lengths: 24mm for a wide view, 50mm for closer-in and 135mm to highlight a region**

Milky Way star fields or areas embedded within them.

The big variable once you get to this type of Milky Way photography, then, is the focal length of the lens you're using. In the collage above, we've highlighted three examples of Milky Way imaging styles at different focal lengths. A 24mm lens gives us a big field of view to work with on a full-format DSLR, which is ideal for wide shots of large swathes of the band of the Galaxy, both on a static tripod or tracking mount. The 50mm lens, meanwhile, can be used for slightly more focused nightscapes on a particular area of the Milky Way, in that case the Galactic core. But it's also a great focal length for capturing deep images of dark dust lanes weaving through the Milky Way's granular spiral arms or prominent constellations through stacking multiple exposures. The last image was taken using a 135mm lens. Focal lengths of 100mm upwards naturally provide much narrower fields of view, so they are best suited to putting deep-sky objects, like clusters and nebulae, in the context of broader Milky Way star fields – the summer and autumn skies in particular provide a wealth of targets for this kind of work.

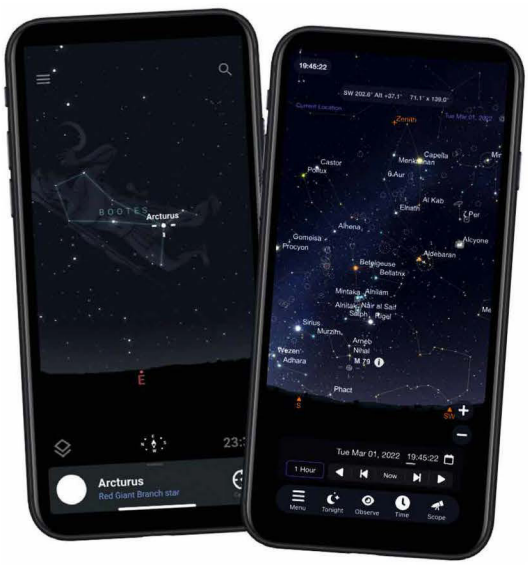
Plan for perfection

Spending time planning your shots will vastly improve your results

Before you go anywhere near the camera shutter button, spend some time planning the composition of your Milky Way images, whether they're nightscapes or more complex captures using a driven mount. Software and apps – such as The Photographer's Ephemeris, Stellarium and SkySafari Plus – will show you where the band of the Milky Way will be in the sky at what time, and the last two also have camera field of view tools that can help you scope out framings with your chosen kit.

Pick your settings

With so much variation in the kind of equipment you could use to shoot the Milky Way, it's not possible to give a 'standard' starting exposure length or ISO setting to use. Instead, the way I'd recommend approaching it is through experimentation, trying to find a good balance between the aperture setting of the lens, the exposure length and the ISO value. For example, opening the lens aperture right up will gather more light, yes, but it will also, on most models, result in more obvious artefacts like the dimming of the corners and frame edges, known as 'vignetting'. It can also exacerbate star distortion around the edge of the frame. Meanwhile, set the ISO too high or too low and you either bring in a lot of noise or don't get the ▶



▶ **Stellarium (left) and SkySafari (right) are both excellent apps to help you plan your nights of imaging**

▲ **How to remove gradients (to rectify light pollution or vignetting from your optics) if your software doesn't have a dedicated tool**

▶ detail you need. And then there are the sky conditions, like light pollution and transparency, whose variable effects you'll need to factor into these considerations.

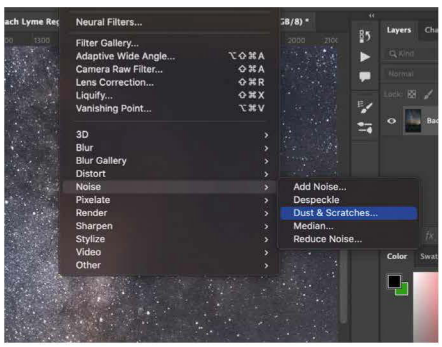
Capturing the data is only part of photographing our Galaxy, however. The post-processing of that imagery is where it can really come to life. We'll get onto processing in a moment, but for widefield Milky Way work there's one common problem that often comes up: gradients, either from the optical system or from light pollution in the sky, or often both.

Grapple with gradients

To tackle vignetting, you can take some very – and I stress *very* – rudimentary flat fields by focusing the lens at infinity and then taking some well-exposed images of a smooth, plain and evenly illuminated white interior wall, which you can use to calibrate data in stacking software later.

If the astronomical processing software you're using doesn't have a built-in gradient removal tool for any remaining gradients, here's one way to tackle

▲ **Create your own basic flat field images by simply shooting a plain, white wall**



▲ **The 'Dust & scratches' tool in Photoshop can be used to remove the stars**

moderate gradients in a program like Photoshop: first duplicate your image as a new layer. Then use a 'Dust & scratches' removal tool to remove all the stars. Then clone out, with the clone or heal tool, any remaining bright stars and Milky Way features in view. Next apply a fairly strong Gaussian blur to the centre 80–90 per cent of the frame using a marquee tool and then 'Select and mask', followed by the blurring filter. Now place this image in the layer below the original image layer and use 'Image > Apply image' with the blending mode set to 'Subtract'. Copy the resultant image into a new layer and process it to taste.

Will Gater is an astronomer, writer and astrophotographer. Visit his website willgater.com or follow him on Twitter: @willgater

WILL GATER X 10

Create a portrait of the summer Milky Way

Using a wide lens, DSLR or bridge camera, a tracking mount and a little processing

Step 1

To fully capture the incredible granular Milky Way star fields, it's crucial to devote time to getting the focus spot on. If you're using a live preview screen for focusing, don't use stars around the periphery of the frame to focus on, as often with wide-angle lenses optical aberrations make it harder to perceive the exact focus point.

Step 2

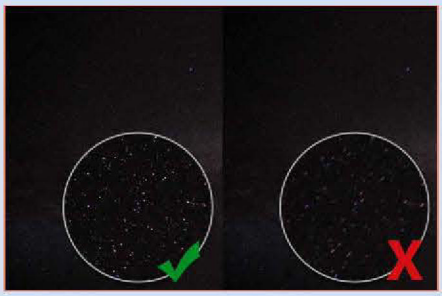
If you haven't already done so, plan your composition in planetarium software (eg Stellarium). Now set your camera to a very high ISO and use short exposures to capture some test shots. For this kind of image it's best not to include any earthly foreground, unless you are happy with it being blurred when we stack frames later.

Step 3

Change the ISO and exposure length to the settings you need to capture your sub-frames. These will be the level at which there's a good balance between the amount of detail you're getting in the star fields and the 'fogging' effect of any light pollution at your site. There's no one-size-fits all, so experimentation is key.

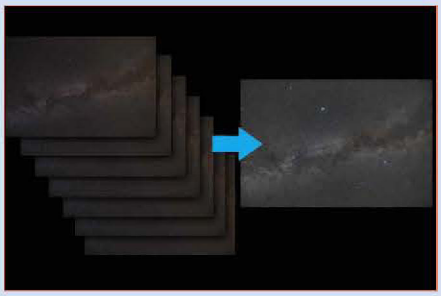
Step 4

With a suitable exposure length and ISO selected, capture at least 10–15 minutes' worth of data in total when shooting your main data. More sub-frames to stack later will help you create a smoother final image, something that's especially important if you're shooting at a high-ISO setting on a static tripod.



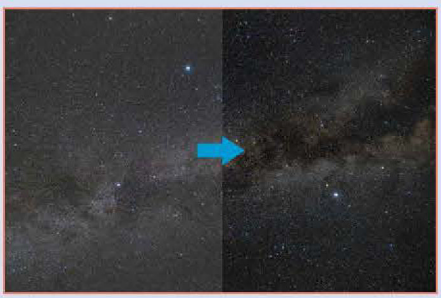
Step 5

Once you're back home, consider if you'll need some 'flat field'-style calibration frames with the lens you used (see opposite for more details). When you have your data loaded onto your computer, inspect each sub-frame carefully and set aside any that show signs of cloud passing through the shot, mount vibrations or wind blurring.



Step 6

You should now have a folder of image files that you've inspected that represent the best frames from your capture sequence. You can now add, or stack, these together in dedicated astronomical processing software, whether that be free programs like DeepSkyStacker or commercial options like Nebulosity or PixInsight.



Step 7

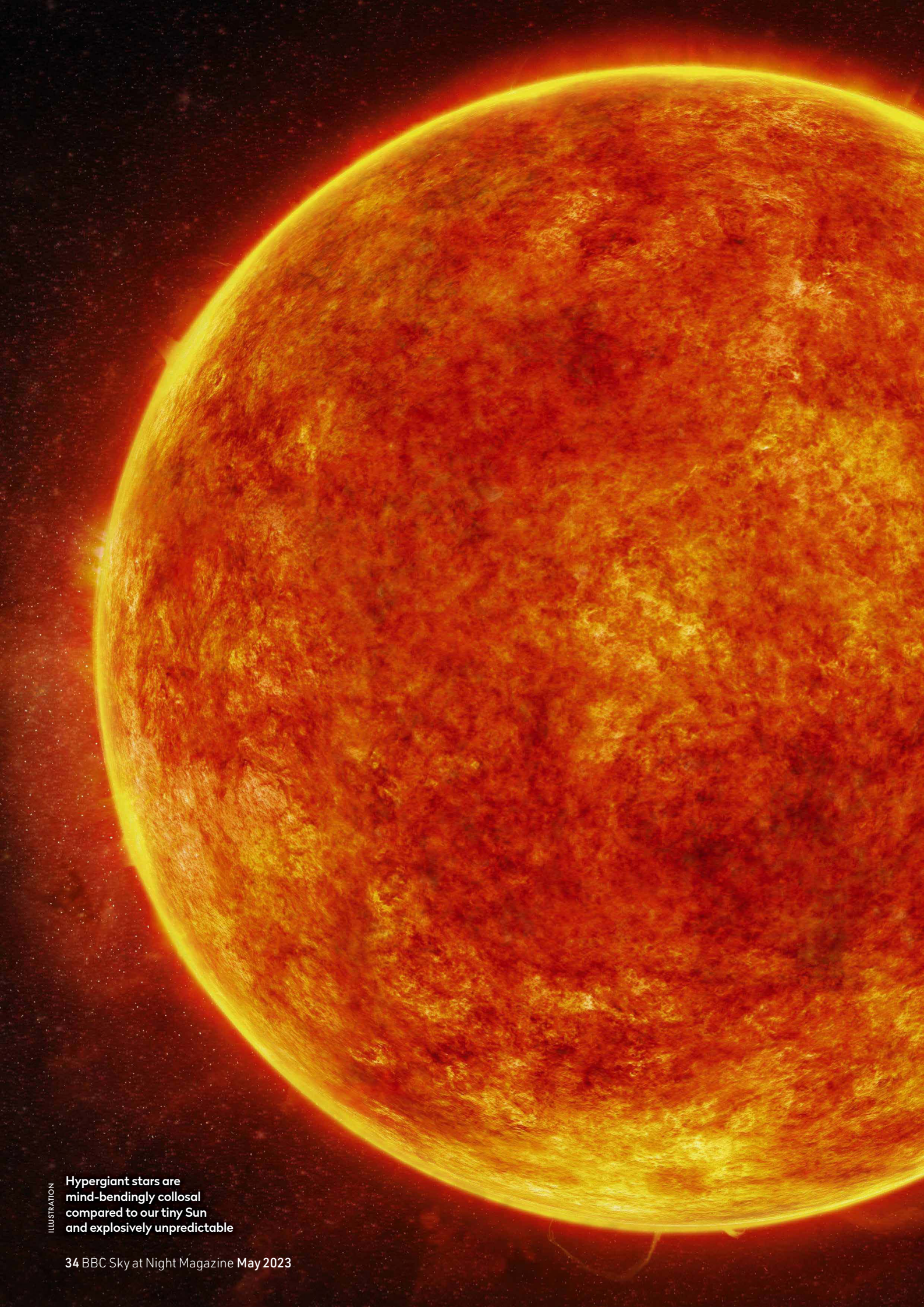
A good first step is to enhance the contrast and brightness of your stacked shot via a gentle Levels or Curves 'stretch'. Using the Curves tool in a program like Photoshop, adjust the diagonal line so that it takes on a subtle 's' shape, bringing up the brighter elements of the image while increasing the contrast in the shadowier parts.

Step 8

If the post-processing software you're using doesn't have gradient or vignetting removal tools, you can do basic gradient removal using the technique outlined opposite. You may then want to return to step 7 to do another round of contrast and brightness enhancements (on the hopefully now-improved image) .

Step 9

Finish with basic colour balancing of your picture. Look for bright(ish) stars in your framing that have a neutral white spectral type (using software like Stellarium as a reference). Then use a colour balance tool in your processing software to adjust the picture's overall colour so that the stars' hue is as close to neutral white as possible.



ILLUSTRATION

Hypergiant stars are mind-bendingly collosal compared to our tiny Sun and explosively unpredictable

The riddle of the HYPERGIANTS

New research is uncovering the weird workings of the largest stars in the Universe, explains **Colin Stuart**

You feel the vibrations as the rocket lifts off from the launch pad. This cramped spaceship is your home for two years as you journey all the way out to Jupiter, the Solar System's largest planet. It's so far away that when you get there the Sun's light is a mere 1/25th as bright as on Earth.

And yet, if you were to make a journey of the same distance in some planetary systems, you'd still be *inside the star*. These celestial beasts – known as hypergiant stars – are colossal. The biggest can fit 10 billion Suns inside, or 14 quadrillion Earths. Such monsters are rare, but they play a crucial role in seeding the Universe with the rich array of chemistry required to sustain life. Their scarcity means they've been poorly understood in the past, but a run of recent research is giving astronomers unprecedented insights into their unique behaviour. Soon we may know their secrets.

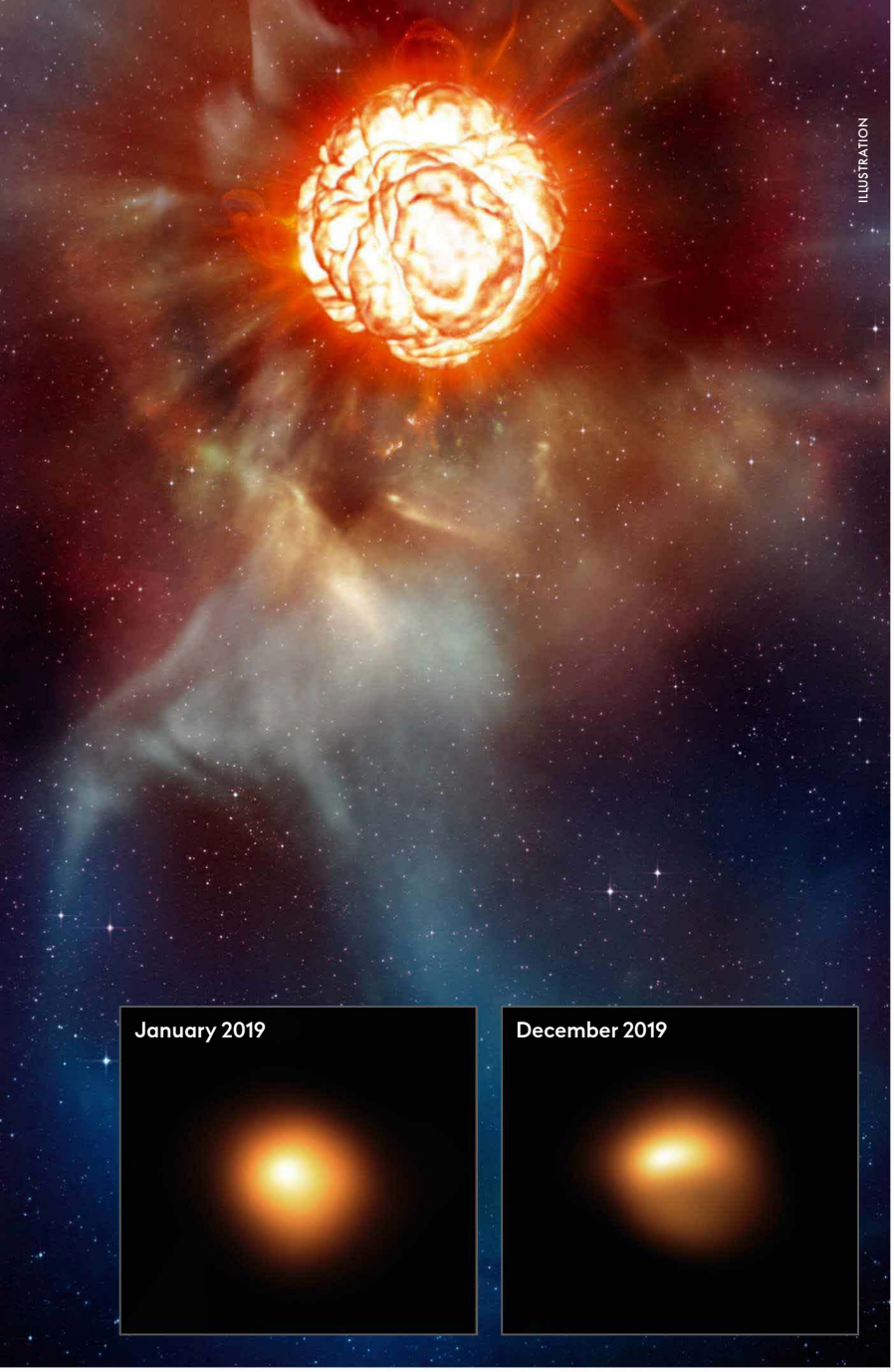
Bizarre behemoths

Hypergiants are so massive, typically dozens of times the mass of the Sun or more, that they are highly unstable. They regularly cough huge quantities of their material back into space. "They are throwing out the mass of Jupiter or more in a single event," says Roberta Humphreys, an astrophysicist at the University of Minnesota.

A similar event on a smaller scale unfolded on the supergiant star Betelgeuse in 2019, when it dimmed noticeably in the night sky before brightening again. Painstaking analysis concluded that it spat out ▶

THE SUN

M. WEISS/CFA



ILLUSTRATION

▲ **Belching Betelgeuse: in 2019, the star blasted off a huge chunk of its surface. Even garden astronomers saw it dim dramatically (inset) as the resultant dust blocked its light**

Our near neighbours the Large and Small Magellanic Clouds house a number of the giant stars

▶ material weighing several times the mass of the Moon from its southern hemisphere. That material blocked out some of Betelgeuse's light, causing the temporary dimming. It was the first time astronomers had seen such a huge ejection from the surface of a star in real time.

Ejected material from hypergiants forms vast and intricate clouds that can stretch out to 10,000 times the Earth–Sun distance from the star's surface. That's over 300 times further out than Neptune, the Solar System's outermost planet, sits from the Sun. "You can clearly see the ejected material forming arcs, lumps, knots and jets around the star," says Humphreys. Individual knots can contain 3,000 Earths' worth of material.

This ejected material enriches the interstellar medium with complex molecules. When gas and dust from several stars mingles, it can collapse to form new solar systems. Fledging planets there will already have the necessary chemical building blocks for biology. In June 2022, Humphreys was part of a team that used the Atacama Large Millimeter Array (ALMA) in Chile to take a closer look at the ejected material surrounding a particularly famous hypergiant: VY Canis Majoris. "Twenty-five different molecules have now been identified there," says Humphreys, including water and silicon dioxide, which is the major constituent of sand.

However, understanding why hypergiants like VY Canis Majoris lose so much mass has been an enduring mystery. A mystery deepened by the rarity of these stellar goliaths. Astronomers know of just 10 hypergiants in the Milky Way, meaning Sun-like stars outnumber them by more than a billion to one. Even then our view of them is often obscured by the huge amounts of dust in our galactic disc.

Stars with a heartbeat

Fortunately, astronomers have also identified a number of hypergiants in the Magellanic Clouds, two of the satellite galaxies that orbit around the Milky Way. Last year, a team led by Michalis Kourniotis from the Czech Academy of Sciences found three of them had something in common: they're pulsating. This could explain why hypergiants are often classified as variable stars. The star's brightness changes in a repeating pattern as it throbs in and out.

Could these pulsations also be behind the ejected material from hypergiants? Humphreys doesn't think so. "Pulsations cannot get the material far enough above the star's surface to the point where the dust and the molecules condense," she says. It simply isn't a powerful enough mechanism to spit material out to the vast distances that ejected material has been seen from hypergiants. The cloud of ejected material from VY Canis Majoris, for example, is some 300 billion kilometres wide – that's over 65 times Pluto's distance from the Sun.

A possible clue comes from the fact that the lost material isn't ejected symmetrically. "It forms projectiles that are fired out in different directions and different angles from different regions of the star," Humphreys says. That points to something

ESO/L. CALÇADA, ESO/M. MONTARGÈS ET AL., MXW PHOTO/ISTOCK/GETTY IMAGES, M. WEISS/CFA, ESO/M. KORNMESSER

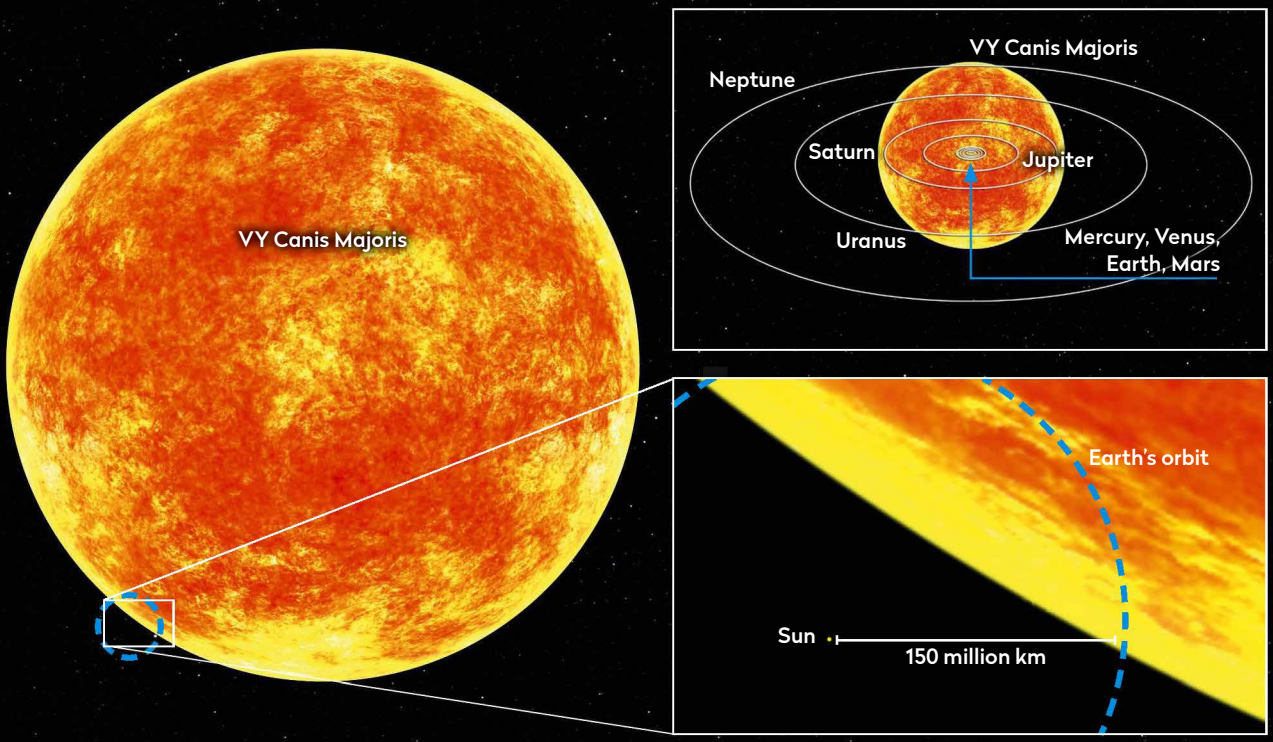
How big is a hypergiant?

The staggering size of these largest of stars is hard to comprehend

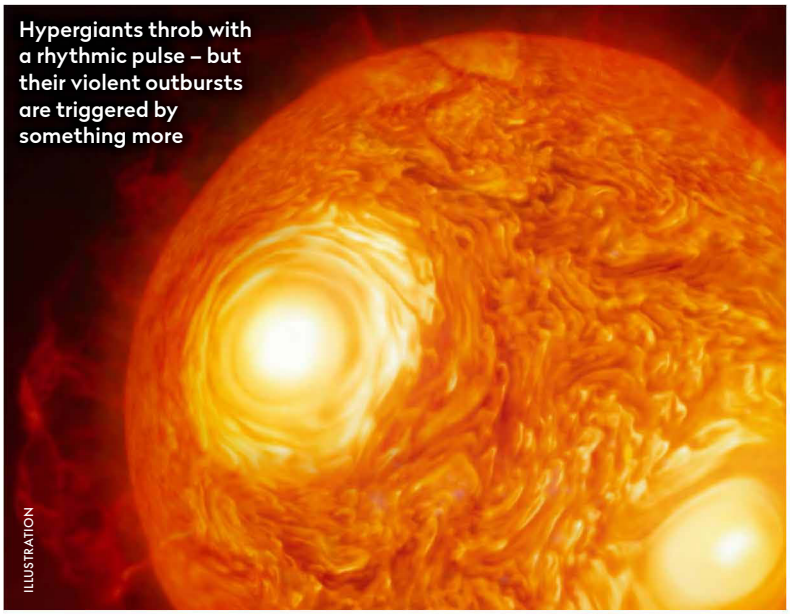
You could fit at least 1,420 Suns across the face of VY Canis Majoris, making its total diameter close to two billion kilometres. Some estimates put it at over 2,000 Suns across, or almost three billion kilometres wide. Earth orbits a mere 150 million kilometres from the Sun, meaning VY Canis Majoris is at least 13 times wider than the Earth–Sun distance.

It would take almost three billion Suns to fill up the star. Even Mercury, the smallest planet, can only fit inside the Sun 21 million times. A supergiant star like Betelgeuse would fit inside this hypergiant eight times over.

Despite travelling at around 300,000 kilometres per second, it would take a beam of light six hours to travel around the circumference of VY Canis Majoris. That's about the same amount of time it took for photos of Kuiper Belt object Arrokoth to travel back to Earth from NASA's New Horizons probe.



▲ How VY Canis Majoris would look if it were our Sun (above right, top), swallowing up the inner planets and extending beyond Jupiter. The mammoth star dwarfs Earth's orbit (above right, bottom) and could accommodate almost three billion of our Suns



Hypergiants throb with a rhythmic pulse – but their violent outbursts are triggered by something more

ILLUSTRATION

going on in isolated regions at the surface, not something happening to the whole star at once.

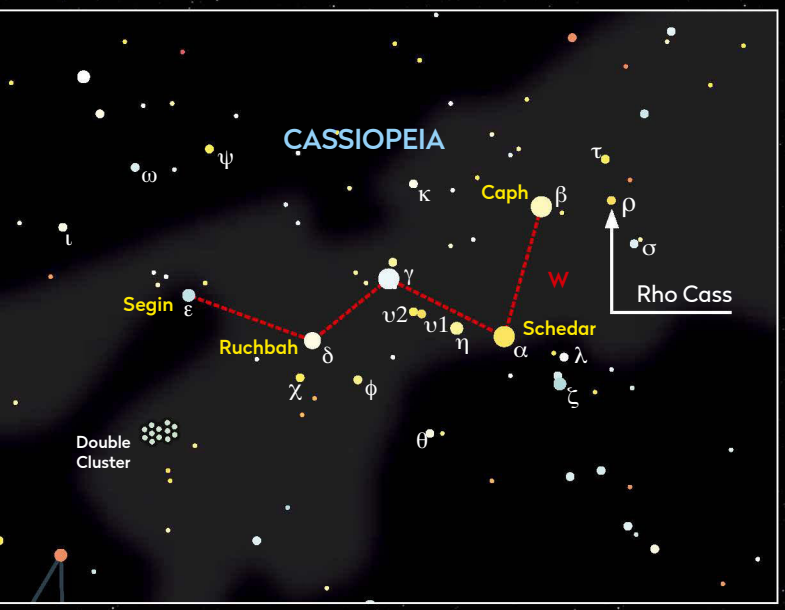
Energy usually reaches the surface of a star through convection. Hot material bubbles upwards, making the star's surface seeth and roil, a bit like a pan of boiling water. This creates convection cells at the star's visible surface. The Sun's convection cells are typically 1,000 kilometres across, but they can take up 60 per cent of the surface of supergiants like Betelgeuse.

Mega magnetism

Perhaps these huge convection cells on the surfaces of hypergiants are destabilising and blasting material into space? "[This idea] has the same problems as pulsations," says Humphreys. Such an event would still not be powerful enough to eject material to the vast distances observed by astronomers. "Something is missing – an additional mechanism is required," she says. The missing piece of the puzzle is magnetism. ▶

Four hypergiant stars to find

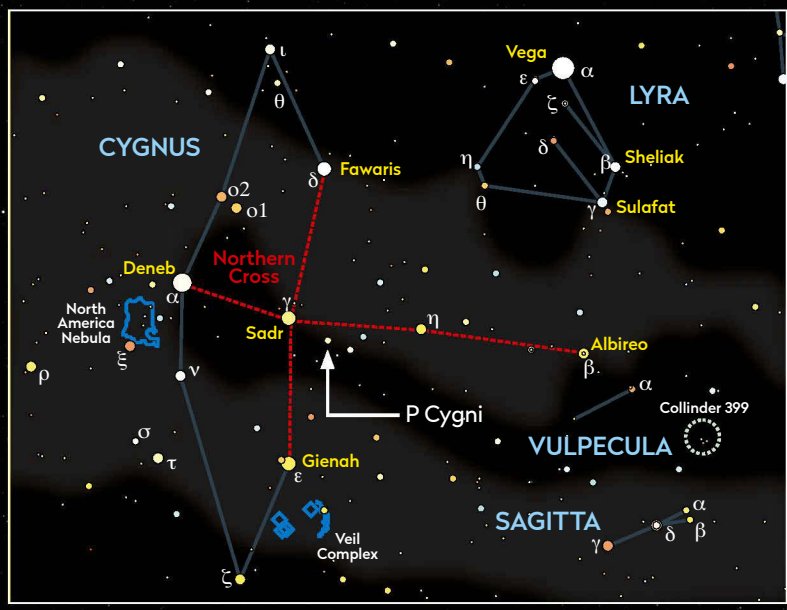
Focus your scope on these bright, giant oddities of the Universe



Rho Cassiopeiae

Magnitude: +4.1 to +6.2

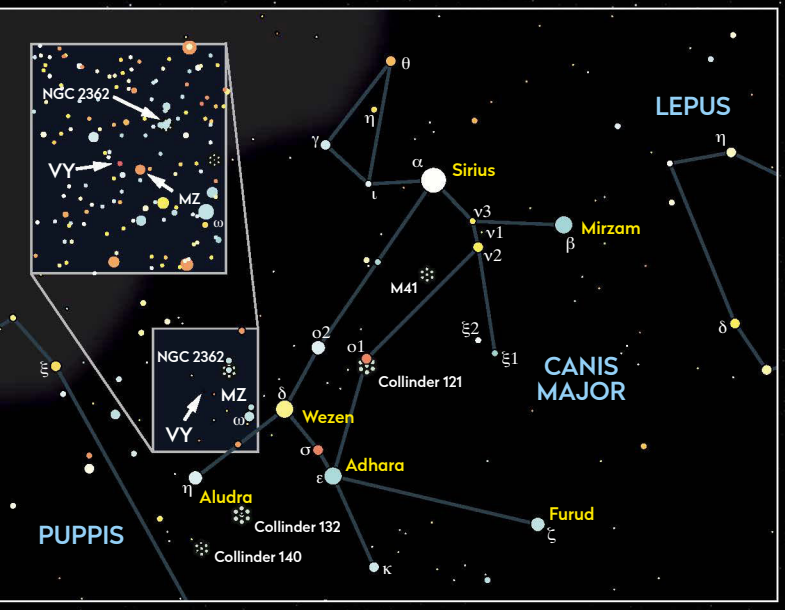
This yellow hypergiant star is located in the prominent W-shaped constellation of Cassiopeia. It's a semi-variable star, meaning its brightness changes over time. Usually it is bright enough to be seen with the unaided eye, but in the past it has temporarily dimmed enough to make binoculars necessary.



P Cygni

Magnitude: +4.8

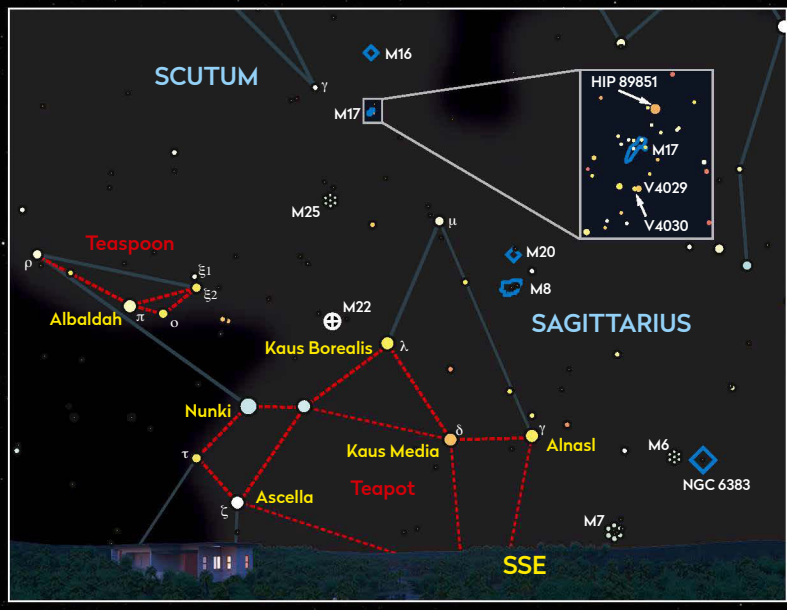
Despite the fact that it is over 5,000 lightyears away, this luminous blue hypergiant is so bright that it's visible to the unaided eye in the constellation of Cygnus, the Swan. You'll find it shining with a magnitude of +4.8 close to where the tail and wings of the Swan meet.



VY Canis Majoris

Magnitude: +6.5 to +9.6

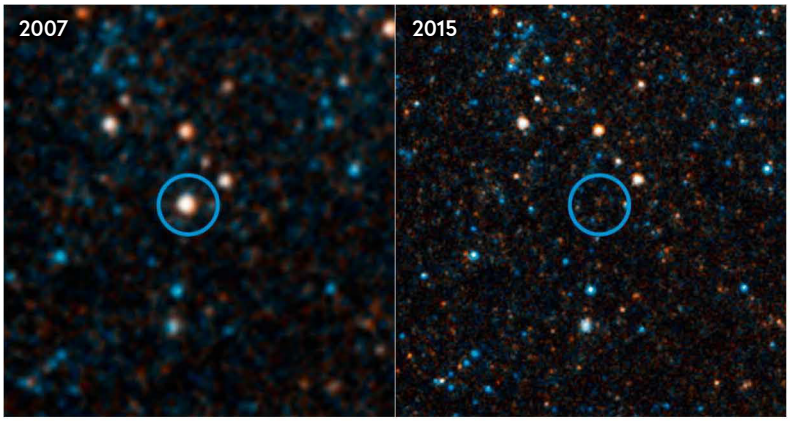
VY Canis Majoris is one the biggest stars in the Universe. This pulsating red hypergiant is located in the constellation of Canis Major, or the Great Dog, diagonally down to the left of Orion's Belt. It's visible from the UK in the winter and very close to the horizon below Sirius.



V 4030 Sagittarii & V 4029 Sagittarii

Magnitude: +8.3

This pair of blue hypergiants is located to the southeast of the Omega Nebula (M17) in the constellation of Sagittarius. The lid of the Teapot asterism points towards them. Sharing a similar brightness, they can be easily seen through a modest amateur telescope low in the south during the summer months.



▲ **The disappearance of N6946-BH1: Hubble Space Telescope shows before and after the gargantuan star vanished, possibly by collapsing into a black hole**

▶ We know from observations of our own Sun that it is highly magnetic. Huge and powerful magnetic fields twist and contort until they snap, flinging huge quantities of material into the Solar System. The most violent of these solar magnetic mood swings is a coronal mass ejection (CME), where the Sun spits out a billion tonnes of material at speeds of over a million kilometres per hour. They are often associated with so-called active regions on the Sun and with other features such as sunspots.

Except even they pale in comparison to similar events on hypergiants. "The strength of the magnetic field is five times greater," Humphreys says. "The energy increases by a factor of a thousand." She argues that, combined with convection, magnetic fields and coronal mass ejections could be the driving force behind the coughing fits of VY Canis Majoris and other hypergiants. The coronal arcs produced would be a billion times larger than those seen on the Sun.

A whimper not a bang

How they lose mass may be getting clearer, but another big mystery remains: how hypergiants die.

It's a puzzle that dates back to 2015, when astronomers noticed the disappearance of a hypergiant star called N6946-BH1 in the spiral galaxy NGC 6946. It was there in Hubble images from 2007, but had vanished from view eight years later. Usually such a massive star would detonate as a cataclysmic supernova when it dies, which would be hard to miss. How could it have simply faded away without so much as a whimper?

There's a hint to one possible answer in the star's name. Stephen Smartt, of Queen's University Belfast, suspects that stars heavier than 17 solar masses – in other words most hypergiants – are so massive that they directly collapse into a black hole (hence BH) without going supernova first.

Humphreys points to another option, though. As hypergiants lose mass they could shrink down, heat up and evolve back into warmer stars. Paradoxically, such a star wouldn't be as bright, because although it is hotter, its surface area has been reduced. That could explain why N6946-BH1 faded from view without going supernova. It's still there, just dimmer and so no longer visible to us from NGC 6946's distance of 25 million lightyears away.

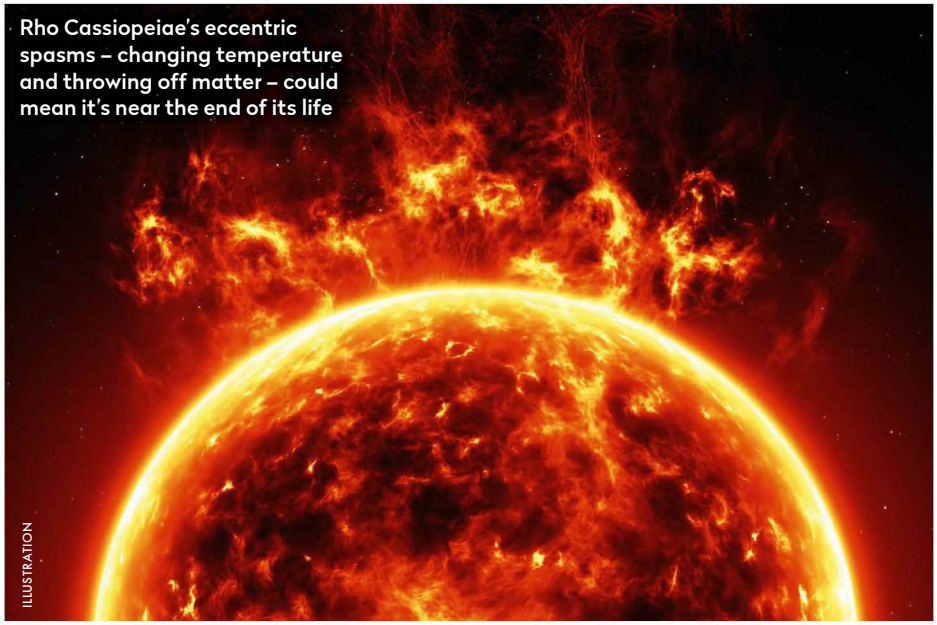
Astronomers could know one way or the other soon. There's another hypergiant star that might just be gearing up for a similar feat. Except this one is in our own Galaxy, giving astronomers a much better chance to see what's going on. It's called Rho Cassiopeiae (or Rho Cas for short).

In June 2022, Grigoris Maravelias, from the National Observatory of Athens, published details of its ejected material. Astronomers have seen Rho Cas experience four major outbursts in the last century, most recently in 2013. Maravelias analysed these episodes and concluded that the outbursts are getting shorter and more frequent. "This activity indicates that Rho Cas may be preparing to pass to the next evolutionary phase," he writes in the paper outlining his findings.

Again, Humphreys is cautious about getting carried away. She points out that there aren't substantial amounts of dust around Rho Cas. "The lack of dust and ejecta could mean the star still has a long way to go," she says.

What will ultimately happen to Rho Cas remains unclear, but it could hold the key to getting under the hood of hypergiants. Astronomers will continue to watch with keen interest, as they look to add the final pieces to the enduring puzzle of understanding the Universe's biggest stars.

Colin Stuart (@skyponderer) is an astronomy author and speaker. Get a free e-book at **colinstuart.net/ebook**



Rho Cassiopeiae's eccentric spasms – changing temperature and throwing off matter – could mean it's near the end of its life

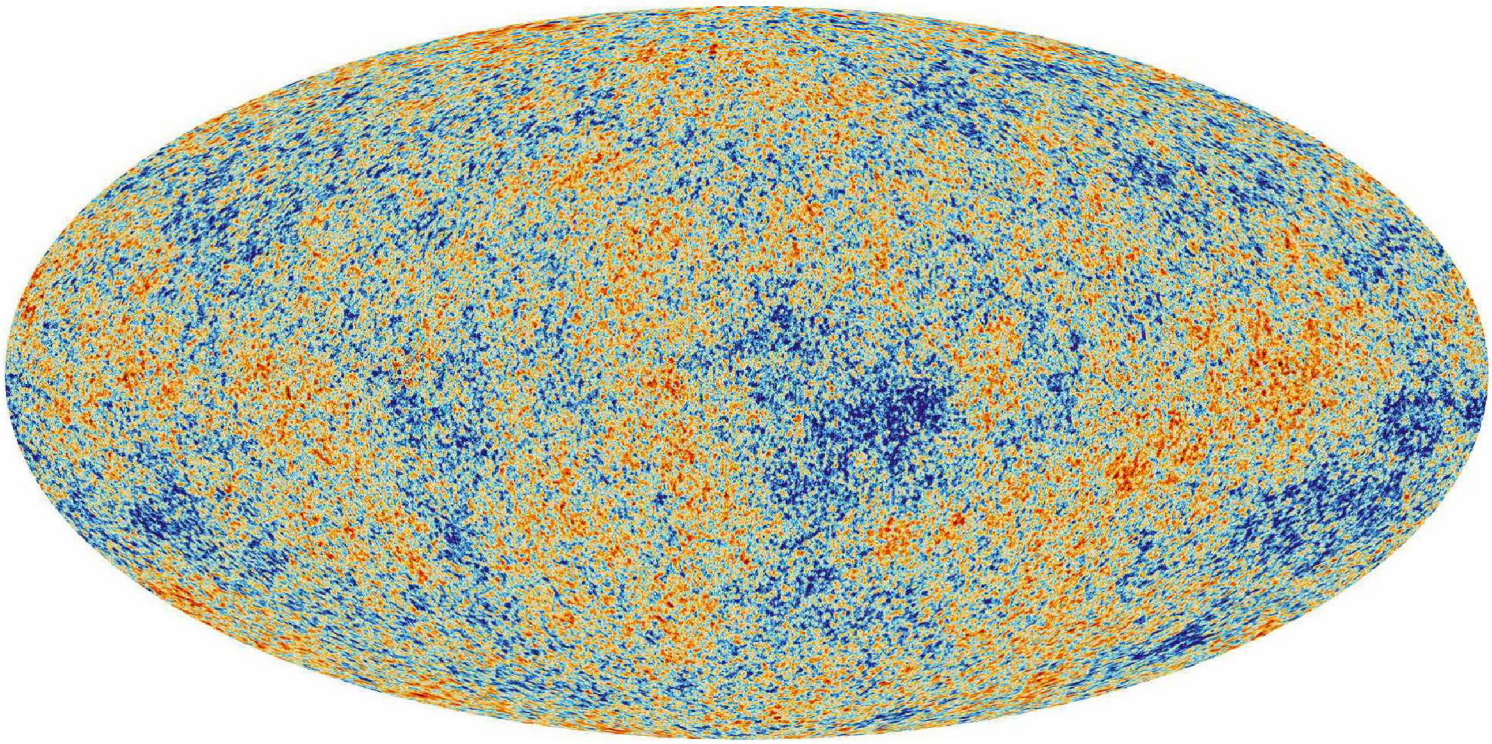
ILLUSTRATION

CHARTS BY PETE LAWRENCE, NASA/ESA/C. KOCHANEK (OSU), ESO

COSMOLOGY CRASH COURSE

How can we see the afterglow of the Big Bang?

Govert Schilling continues to explain some of cosmology's most confusing concepts



ESA AND THE PLANCK COLLABORATION, CFA/M. WEISS, ALEXANDER SPATARI/ISTOCK/GETTY IMAGES

▲ **The baby Universe post-Big Bang – Planck's snapshot of the primordial radiation that still pervades the cosmos today**

This month, we'll take a closer look at the cosmic microwave background. Sometimes called 'the afterglow of creation', this extremely faint microwave glow is considered one of the most convincing pieces of evidence for the Big Bang theory. But how is it that we are still observing this ancient light?

As we've seen in earlier parts of this series, space is expanding. Since the amount of matter in the Universe remains fairly constant, the increasing volume means that the average density of cosmic matter is decreasing over time. That means the density of the Universe must have been much higher in the distant past.

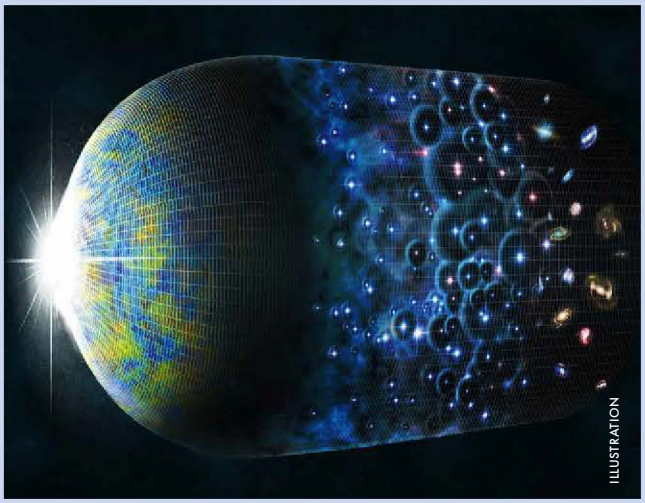
Right after the Big Bang, before there were any galaxies, stars or planets, elementary particles were packed almost shoulder to shoulder, and the corresponding temperature was unimaginably high. This hot, dense plasma produced energetic radiation. However, individual light particles – photons – have trouble traversing such plasma-filled environments, as they are continuously absorbed (and re-emitted) by charged particles like electrons. In other words: the hot, early Universe was opaque.

As space expanded, it cooled, and when temperatures dropped below around 2,700° Celsius (much cooler than the surface of the Sun), electrons could combine with protons to form electrically neutral hydrogen atoms. From then on, photons could freely stream through space, in all possible directions. The Universe became transparent. This happened some 380,000 years after the Big Bang. (Incidentally, the average density of the Universe at

Cosmic treasure trove

Leftover radiation from the explosion is key to unlocking the Universe around us

The cosmic microwave background was discovered in 1964 and studied in incredible detail by the European Planck mission. It turns out not to be completely homogeneous: there are minute temperature variations in the CMB we see today, created by small density fluctuations when the Universe was around 380,000 years old. Over the course of its 13.8-billion-year history, these density fluctuations have given rise to the rather clumpy large-scale structure of the present Universe, with galaxies, clusters, and superclusters. This growth process was governed by the global properties of the cosmos, such as the abundance of 'normal' and dark matter, the expansion rate and the amount of dark energy. By meticulously comparing the Planck data with observations of today's Universe, scientists have been able to quantify these cosmological parameters to a high accuracy, even though the true nature of dark matter and dark energy is still a mystery.



▲ The constant background signal is the last remnant of the Big Bang's light – and it's loaded with clues about the early Universe

that time was already extremely low: just some 1,000 atoms per cubic centimetre.)

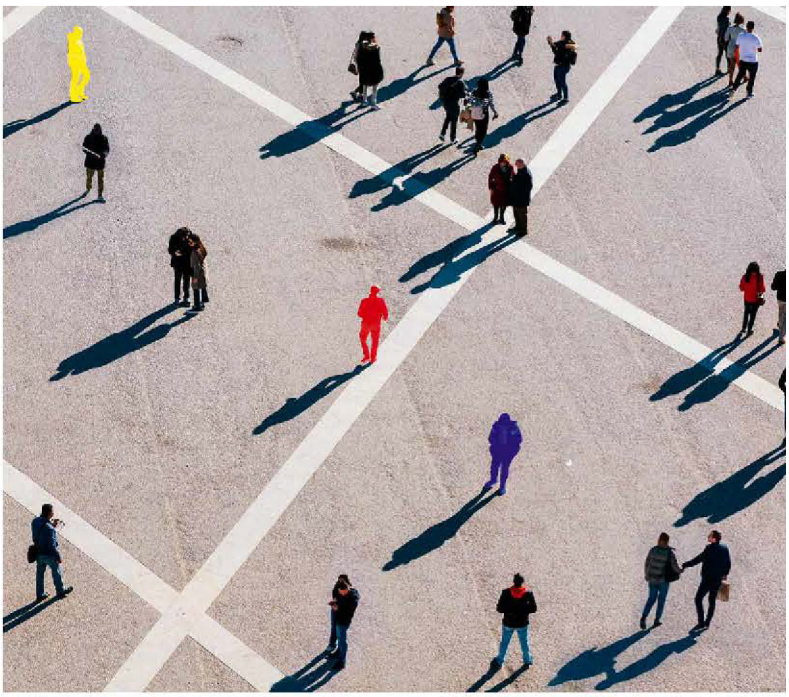
The radiation that was finally 'released' when the Universe was 380,000 years old is called the cosmic microwave background (CMB). Although this radiation was originally emitted at optical wavelengths, it has travelled through expanding space for almost 13.8 billion years and as a result the waves got stretched all the way into the microwave part of the electromagnetic spectrum.

Everything everywhere all at once

But if this radiation was emitted at more or less one single moment in time, how is it that we are still able to keep observing it? And why do astronomers see it all over the sky? Shouldn't the CMB have passed us long ago as a brief flash of light, coming from one particular direction?

Well, no. Remember that the Big Bang was not some fireworks explosion taking place at a particular location in empty space. Instead, *all* of the Universe (including the part that we currently inhabit) was once in a state of extremely high density and temperature. The primordial radiation emitted by our part of space some 380,000 years after the Big Bang has long disappeared into the distance. But photons emitted by other, very remote parts of the Universe are only now arriving at Earth.

Imagine you are on a large city square filled with people, and let's assume (for the sake of convenience) that the speed of sound is just one metre per second – much lower than its true value. If everyone is asked to shout 'Boo!' at exactly 12:00:00, your own shout will die out pretty soon. But 10 seconds later, at 12:00:10, you will hear the shouting from people who are 10 metres away. At 12:01:00, the shouts from people at 60 metres distance will hit your ear drums. Even at 12:10:00, 10 minutes after everyone produced their instantaneous 'Boo!', you receive the (softer) sound from a distance of 600 metres.



▲ In our symbolic Universe, the blue person (our Galaxy) hears the noise (CMB) from the red person (a distant galaxy) after 10 seconds and from the yellow person after one minute, even though they both shouted at the same time

Govert Schilling's book *The Elephant in the Universe* is published by Harvard University Press

The same is true for the cosmic microwave background. It was 'emitted' everywhere in space at more or less a single moment in time, but since it travels at a finite speed (the speed of light), we keep receiving the signal from ever-further regions of the Universe. Today, 13.8 billion years after it began its journey, it arrives on Earth from parts that are now some 45 billion lightyears away – our cosmological horizon. Little wonder that it's such a faint signal!

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16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

The Sky Guide

MAY 2023

RARE ENCOUNTER

Jupiter gets a close daylight visit from the Moon, an occultation for some

DEEP-SKY TOUR

Beautiful Messier targets to unearth near the Plough

NOCTILUCENT CLOUDS

Will you spot the elusive night glow?

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Favourable northern lunar libration
- Observe Venus reaching dichotomy
- Get to know the Moon's Mare Crisium

Red light friendly

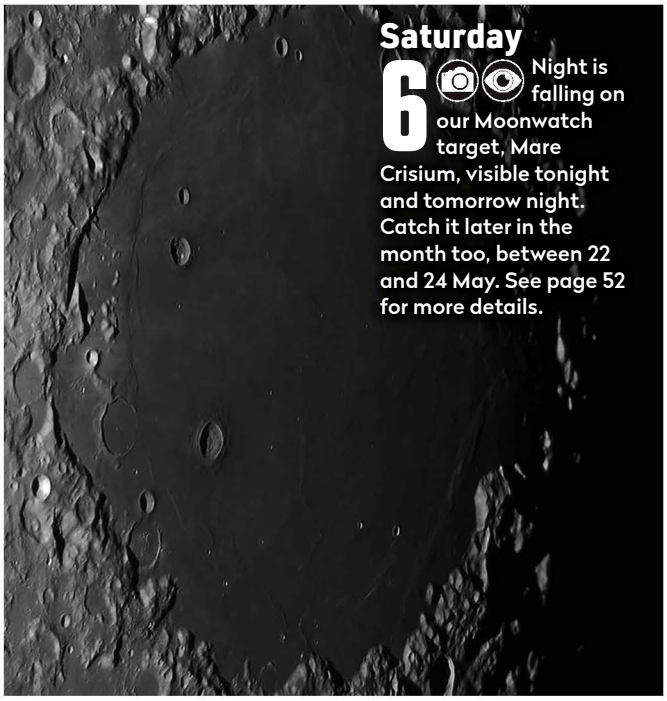
To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

MAY HIGHLIGHTS

Your guide to the night sky this month



Saturday 6

Night is falling on our Moonwatch target, Mare Crisium, visible tonight and tomorrow night. Catch it later in the month too, between 22 and 24 May. See page 52 for more details.

Sunday 7

Eta Aquariid meteor shower reaches peak activity this morning but a bright, just-past-full Moon in the sky will cause issues this year.

Monday 8

From now until 23 May is a good time to check out this month's Deep-Sky Tour (see page 56) which is looking at targets near the Plough.

Wednesday 10

After moonset, view Corona Borealis high in the south around midnight BST. Here lies the irregular variable star R Coronae Borealis, which varies between mag. +5.7 and +15. Have a look and see if it's visible.

Thursday ▶ 11

Lunar libration and phase favours the northern polar region of the Moon at the moment, a good opportunity to look out for rarely seen features such as craters Hermite (111km) and Rozhdestvenskiy (177km).

Tuesday 16

Venus is 0.7° north of Mebsuta (Epsilon (ε) Geminorum). The pairing is visible as darkness falls and Venus approaches the northwest horizon.

◀ Wednesday 17

Today, the 5%-lit Moon and Jupiter have a very close encounter, resulting in a rare lunar occultation of the gas giant as seen from the northern part of the UK. See page 46 for details.

Tuesday 23

Tonight the May Camelopardalids meteor shower reaches peak activity.

A 14%-lit crescent Moon passes 1.7° north of mag. –4.1 Venus during daylight hours.

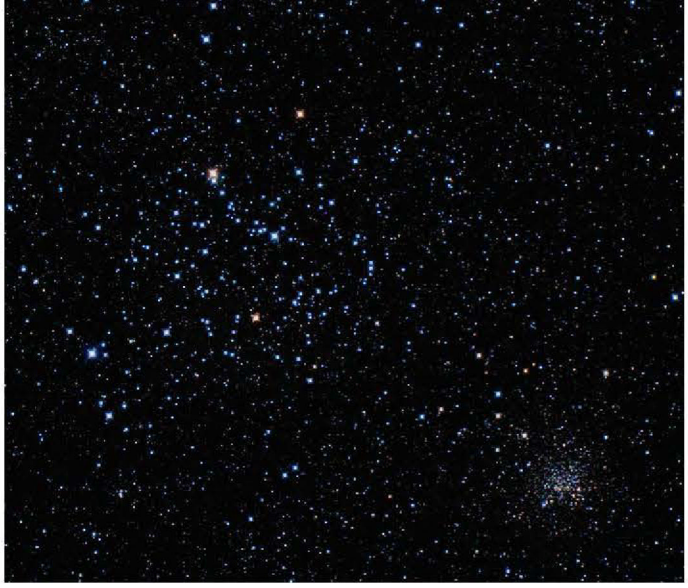
Wednesday ▶ 24

This evening the 25%-lit waxing crescent Moon lies 3° north of mag. +1.5 Mars.

Family stargazing

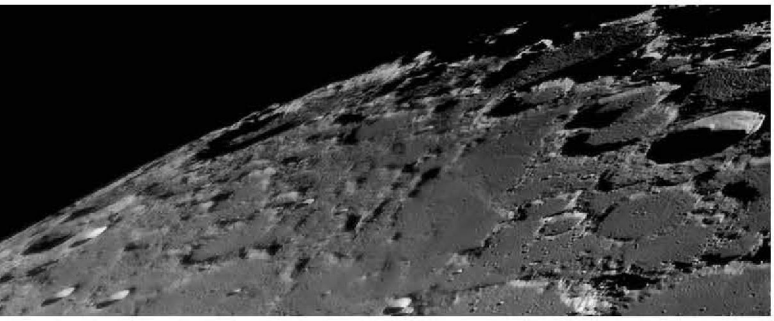
Venus is a very bright evening planet right now and relatively easy to find with a telescope. Even a small scope will reveal its phase, which this month shrinks from 66% to nearly 50% illuminated, when it appears like a bright semi-circle. While obvious at the moment, Venus will become harder to see in the coming months. Getting into the habit of looking at it and drawing its phase is an excellent way to get into observing Venus. Encourage keeping a notebook of any drawings made, recording the date, time and the telescope you used. **www.bbc.co.uk/cbeebies/shows/stargazing**

PETE LAWRENCE X 8



Tuesday ▶ 9

Mag. –4.1 Venus is located 1.8° north of the mag. +5.0 open cluster M35 this evening. It's a tricky catch as the sky only gets dark enough to see the cluster stars as Venus approaches setting.



Friday 12

Before the dark skies totally slip away as we approach the June solstice next month, check out our Star of the Month, Diadem (Alpha (α) Comae Berenices) on page 53.

Sunday 21

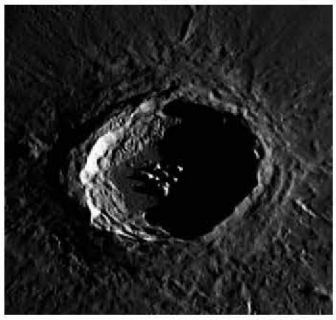
Minor planet 44 Nysa reaches opposition, shining at mag. +10.3 near the border between Scorpius and Libra.

Monday ▶ 22

It's time to look out for noctilucent clouds. If they are present, they are typically seen low above the northwest horizon 90–120 minutes after sunset or a similar time before sunrise, low above the northeast horizon.

Saturday ▶ 27

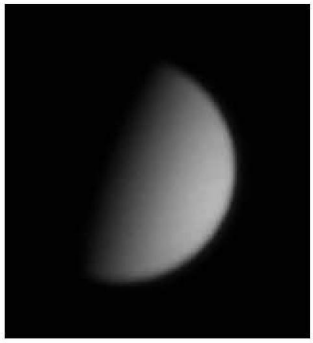
The clair-obscur effect known as the Stars of Aristillus is visible this evening. It occurs when the central peaks within crater Aristillus catch the early light of the lunar dawn.



Monday 29

Mercury reaches greatest western elongation, separated from the Sun by 24.9° in the morning sky.

The Jewelled Handle clair-obscur effect is visible on the Moon tonight.



◀ Tuesday 30

Viewing Venus through a telescope reveals the planet approaching 50% illumination. Venus's 'phase anomaly' means the phase you observe is different to the phase predicted for that date. When do you think Venus looks 50%-illuminated?

Wednesday 31

As it approaches setting, Mars will be just to the west of the Beehive Cluster, M44. The planet is due to pass in front of the cluster in early June.

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **bit.ly/10_easylessons** for our 10-step guide to getting started and **bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE

The top sights to observe or image this month

DON'T MISS

Lunar occultation of Jupiter

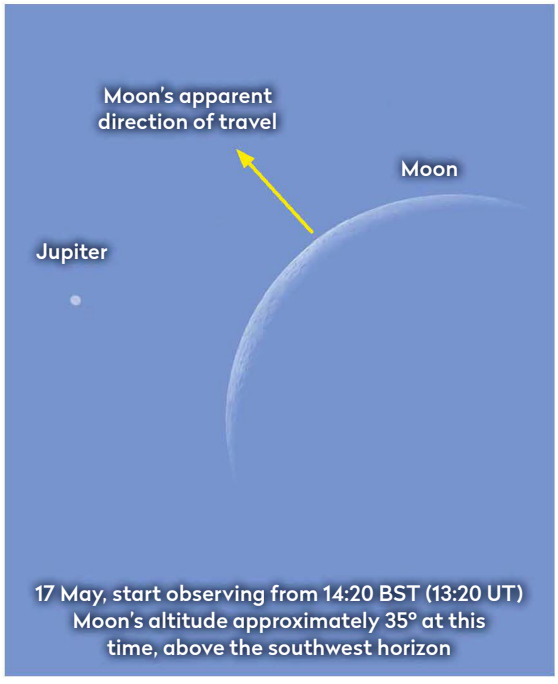
BEST TIME TO SEE: 17 May, from 11:30 BST (10:30 UT) through to 15:30 BST (14:30 UT)

Lunar occultations of planets aren't very common at all. If you've been following events over the past few months, you might question this statement seeing as there have been three recent lunar occultations of Uranus and one of Mars visible from the UK. However, delve back before the first event, the lunar occultation of Uranus on 14 September 2022, and there weren't any for several years before that. This month there's a very rare lunar occultation of Jupiter, an event which comes with a couple of catches.

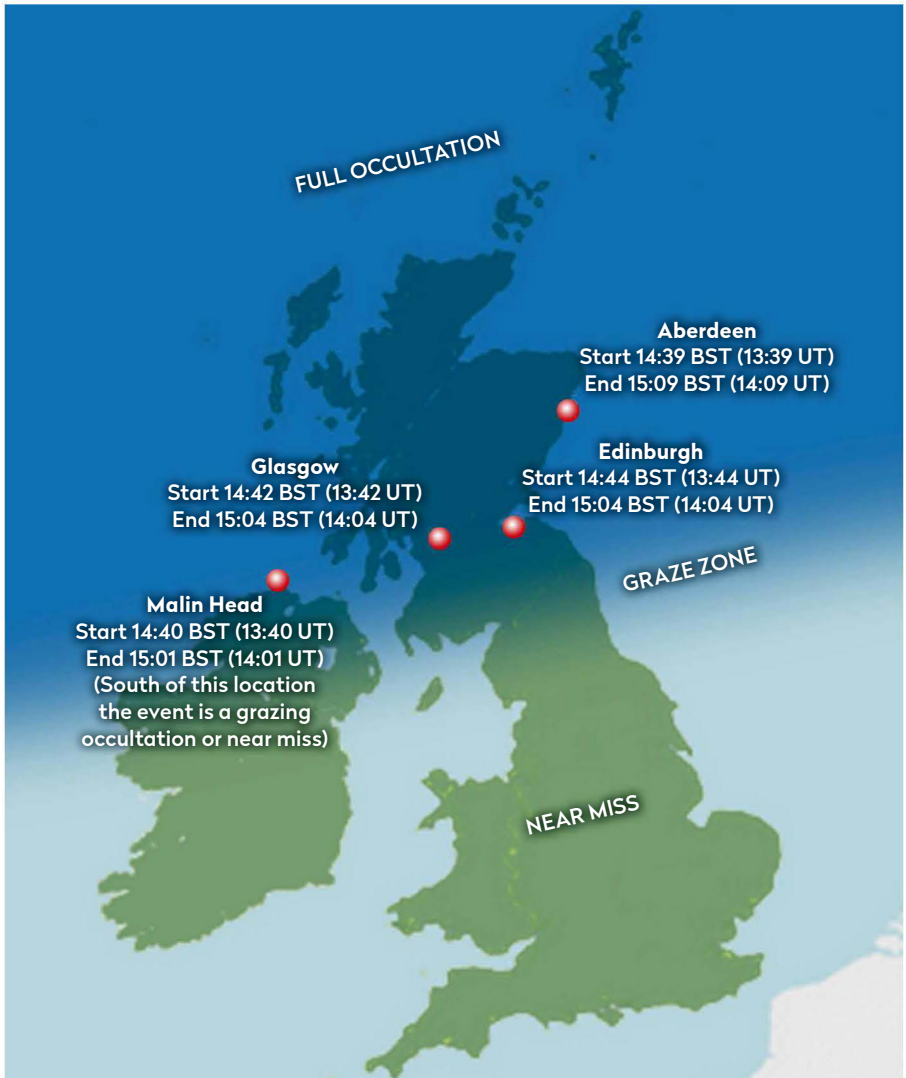
Jupiter is a morning planet currently, not particularly well-placed and rising just 50 minutes before the Sun, mid-month. As it pops up above the east-northeast horizon on the morning of 17 May, it will be accompanied by a slender, but quite visible 7%-lit waning crescent Moon. From the UK, the Moon will appear 5° to the right of mag. –1.9 Jupiter. Fifty minutes later, the Sun will rise and, if the weather is kind, the sky will turn bright blue.

At this point, you're probably anticipating the first catch: the occultation occurs during daylight hours from the UK. Having said this, it's still a perfectly feasible observation, although it will lack the spectacle of a nighttime lunar occultation of a bright Jupiter.

The Moon will be visible to the naked eye given cloud-free skies, but being a relatively thin crescent, it may need a bit of work to find. The pair are due south at 47° altitude from central regions of the UK at 11:24 BST (10:24 UT) on 17 May. This is a good time to try for the Moon using a telescope on a driven equatorial mount. The Sun is only 27° away though, so if you're using binoculars or the naked eye to locate the Moon, take care and do so in the shadow of a house, fence or some other opaque obstruction that leaves the region to the right of the Sun clear.



At 14:30 BST (13:30 UT), Jupiter will appear like a ghostly echo of its nighttime self, close to the Moon's southern edge. Now for the second catch: the occultation can only be seen from the north of the UK, mostly from Northern Ireland and Scotland. Those living in the fuzzy 'graze zone' may see Jupiter partly occulted by the Moon's limb, while those further south will witness a near miss. Approximate timings for various locations are shown on the map below, observing being recommended from 14:20 BST (13:20 UT) through to 15:20 BST (14:20 UT).



▶ **Location makes a big difference to what you'll actually see, producing either a close pass, graze or full occultation**

ALL PICTURES: PETE LAWRENCE

Venus at dichotomy

BEST TIME TO SEE: 25 May–14 June

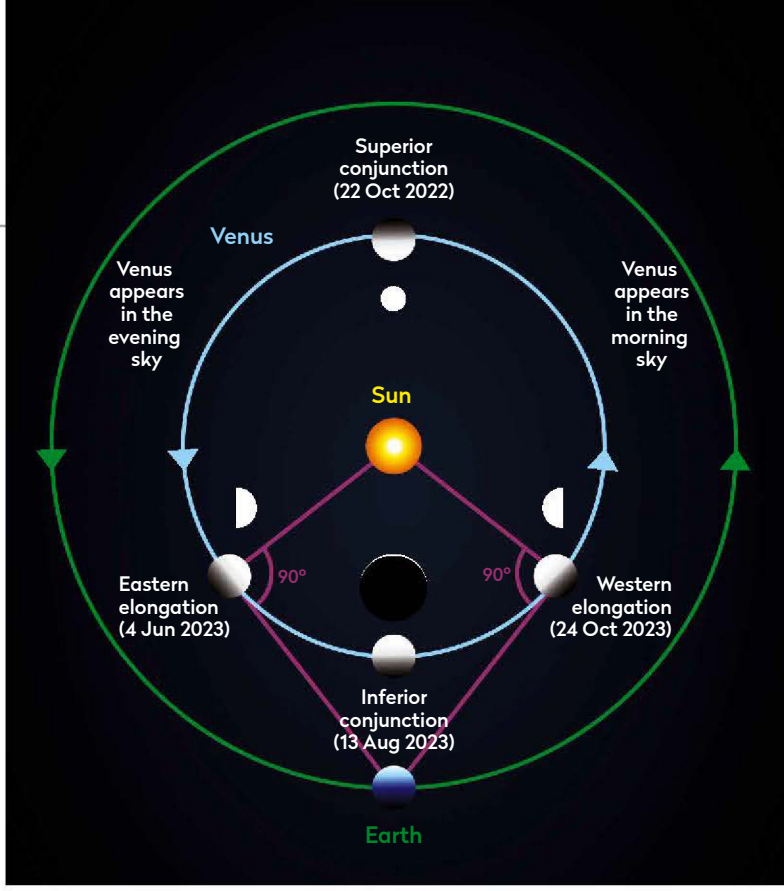
Venus is an inferior planet. This doesn't mean it's a lesser world than ours, it's simply a reference to the size of its orbit. Inferior planets have smaller orbits than Earth, superior planets larger orbits. Mercury and Venus are inferior planets, the rest are superior.

Inferior planets are interesting to observe as their apparent sizes wax and wane noticeably over time and they show a full set of phases. Venus reaches greatest eastern elongation on 4 June, appearing 45.4° to the east of the Sun and brilliant in the evening twilight. The planet should appear at 50% phase, known as dichotomy, on this date.

The run up to dichotomy, say from 10 days before, is a good time to start making phase estimates and they're really easy to do. Simply observe Venus through the eyepiece, noting whether the planet's terminator is straight or curved. If straight, this is dichotomy. If curved, estimate how far across the diameter of Venus – at right angles to the terminator – the terminator extends. As an example, if the terminator stretched one-third across the diameter of Venus, this would be a 33% phase.

Starting to observe early gives you more experience at making accurate assessments. It's easy to look and record '50%' at a first glance, but is it really 50% or perhaps a little above or below that?

Why bother to do this? Surely the geometric position of Venus will give a precise and predictable value for its phase? Actually, this is not the case. The planet's thick atmosphere interferes with the apparent phase, giving rise to the 'phase anomaly', an effect that makes dichotomy appear earlier than it should when Venus is in the evening sky. How early? Well, that's up to you to find out!



▲ Venus's changing appearance as it orbits; it's now approaching 50% lit (dichotomy)

2023's NLC season

BEST TIME TO SEE: Last week in May through to early August


Watch out for these shimmering clouds at sunrise and sunset

Noctilucent clouds (NLCs) are high-altitude ice-sheet clouds that form in the mesosphere at a height of around 82km. For the Northern Hemisphere, NLC season runs from late May through to early August and spotting their elusive displays is a popular pastime, helping to counter the frustration of the shorter nights. NLCs are seeded by fragmentary dust from meteor trails. Tiny ice crystals form around these particles when the mesosphere cools. Mesospheric cooling, rather counter-intuitively, occurs in each hemisphere's summer period.

If present, NLCs are typically seen 90–120 minutes after sunset, low above the northwest horizon, and a similar time before sunrise low above the northeast horizon. At such times, it's dark or at least deep-twilight dark for us on the ground, but the clouds appear to shine. The light is from the Sun; at the great height of an NLC cloud the Sun still appears above the horizon.

NLCs often have an electric blue colour and exhibit fine, net-like structures. Appearing bright against a dark twilight sky, they are also very photogenic and may be bright enough to image with many models of smartphone camera.

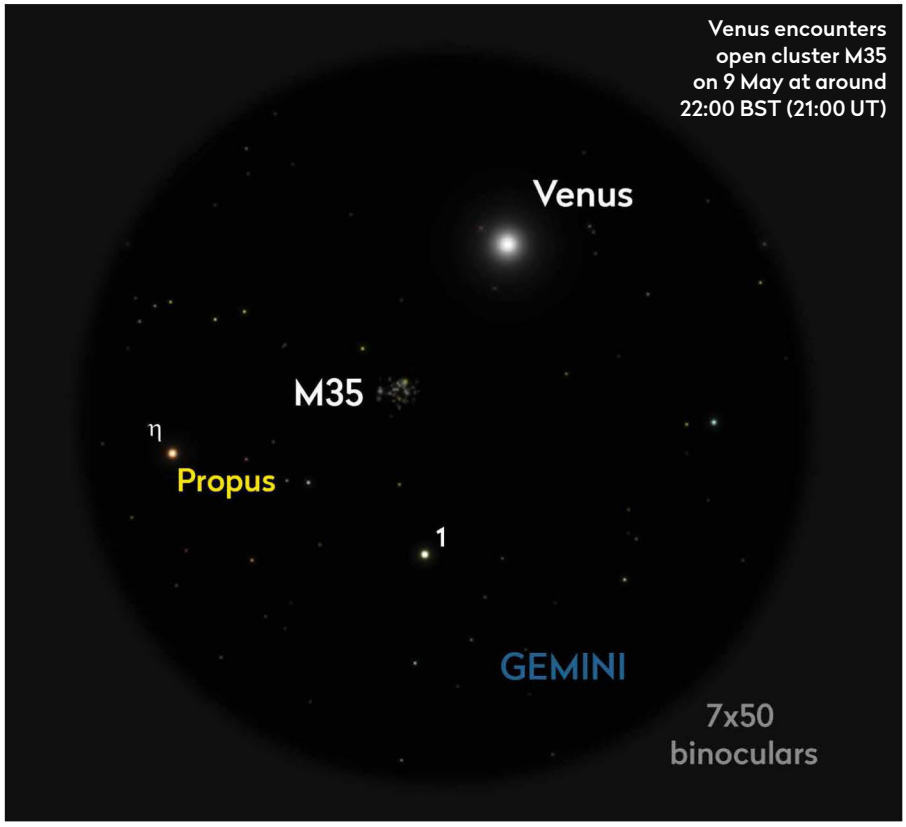
THE PLANETS

Our celestial neighbourhood in May

PICK OF THE MONTH

Venus

Best time to see: 1 May, from 1 hour after sunset
Altitude: 24°
Location: Taurus
Direction: West-northwest
Features: Phase, subtle surface markings
Recommended equipment: 75mm or larger



Venus is a spectacular evening planet throughout May, despite its brilliance being constantly challenged by the bright, expanding spring evening twilight. On 1 May, shining at mag. –4.0, Venus sets 4 hours and 15 minutes after the Sun, giving you approximately 2 hours to view it against a dark sky as it approaches the northwest horizon.

On 9 May, now shining one-tenth of a magnitude brighter at –4.1, Venus sits 1.8° to the north of the mag. +5.1 open cluster M35 in Gemini. You'll need a flat northwest horizon to see this encounter at its best though, as the pair are low when true darkness falls, about 8.5° as seen from the centre of the UK.

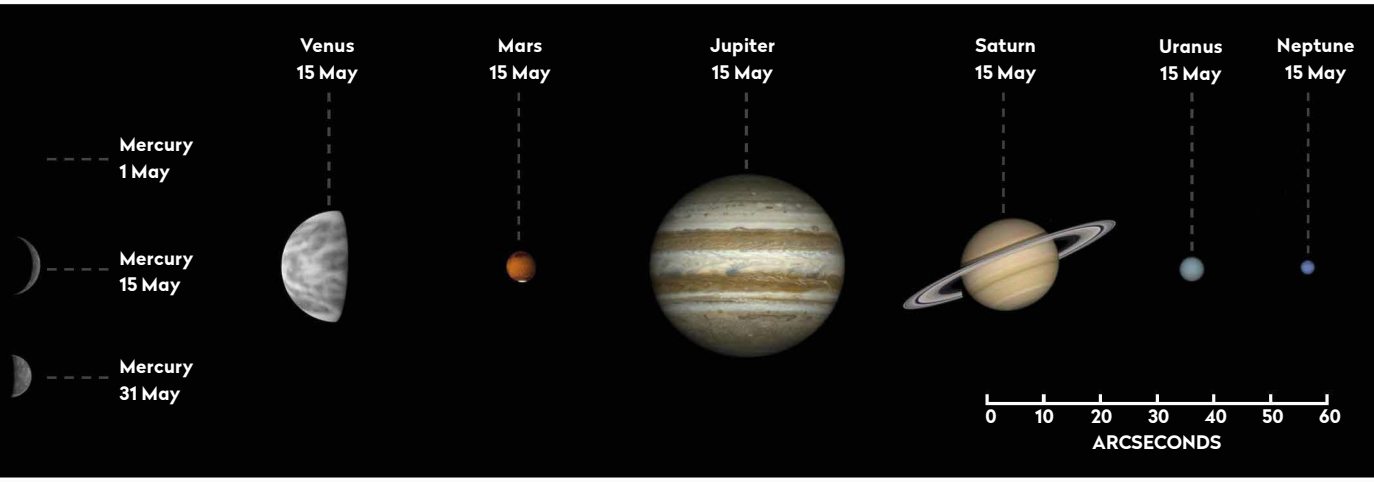
On 16 May, Venus sits three-quarters of a degree from Mebsuta (Epsilon (ε) Geminorum). All the while, the period when you are able to see Venus against a dark sky will be shrinking, the planet's altitude decreasing significantly when true darkness falls throughout the month. Mid-month, Venus remains above the horizon for 4 hours after sunset and through a telescope appears 60%-lit. Its disc will appear nearly 20 arcseconds across on this date.

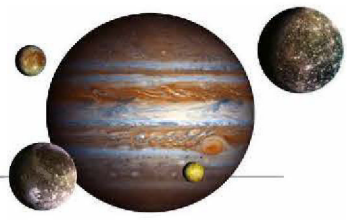
Venus's monthly visit from the Moon is a two-evening affair during May. The mag. –4.1 planet has a visit from a 10%-lit waxing crescent Moon 6.8° to the right and slightly below it on the evening of 22 May, and a 17%-lit waxing crescent 4.8° east (above and left) of it on the evening of 23 May. On 31 May, the bright evening twilight starts to win against Venus and it will no longer be possible to see the planet against truly dark skies from the UK. On 31 May, Venus sets 3 hours 30 minutes after the Sun.

PETE LAWRENCE X 2

The planets in May

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Not visible

Mercury is at inferior conjunction on 1 May. Subsequently moving into the morning sky, it's not well-placed, rising shortly before sunrise most of the month. By the end of May, Mercury shines at mag. +0.5, only rising 40 minutes before the Sun.

Mars

Best time to see: 1 May, from 23:00 BST (22:00 UT)
Altitude: 26°
Location: Gemini
Direction: West

Mars is a mag. +1.3 evening planet in Gemini on 1 May and through the month it loses altitude as darkness falls. On the evening of 23 May, mag. +1.5 Mars lies 14.5° west of mag. –4.1 Venus. A beautiful 17%-lit waxing crescent Moon sits between both planets. On the following evening, the 25%-lit waxing crescent Moon sits 3.2° above Mars. Both will be near the Beehive Cluster, M44, at this time, but late twilight and low altitude will make M44 hard to see. On 31 May, mag. +1.6 Mars knocks on the western side of M44, the cluster stars being really hard to see due to low altitude and bright twilight. Mars appears 4 arcseconds across at the end of May.

Jupiter

Best time to see: 17 May, from 14:20 BST (13:20 UT)
Altitude: 35°
Location: Pisces
Direction: Southwest (daylight)

Jupiter was in conjunction with the Sun last month and isn't well-placed. Your best chance of spotting it will be in the early morning dawn twilight, low above the east-northeast horizon at the end of the month. On the morning of 17 May, a slender 7%-lit waning crescent Moon sits 5° southwest of mag. –1.9 Jupiter as they both rise above the east-northeast horizon 50 minutes before sunrise. Stay with the Moon after sunrise using a telescope and it may also be possible to maintain a ghostly view of Jupiter. The Moon continues to close in on the planet, occulting it as seen from northern UK, or passing just to the north of it as seen from southern UK.

Saturn

Best time to see: 31 May, from 03:00 BST (02:00 UT)
Altitude: 6° (low)
Location: Aquarius
Direction: East-southeast

Low in the east-southeast, Saturn is visible in the dawn twilight. It is currently a morning object, not well-placed. The best time to see it is at the end of the month when, under brightening twilight, it reaches around 12° above the southeast horizon. When solar conjunctions occur before or around the June solstice, as is currently the case, the re-emergence of the main planets from the Sun's glare tends to be poor. More encouragingly, the 2023 oppositions of Jupiter and Saturn are looking promising, with relatively good altitude.

Uranus

Not visible

Uranus is in conjunction with the Sun on 9 May and not currently visible.

Neptune

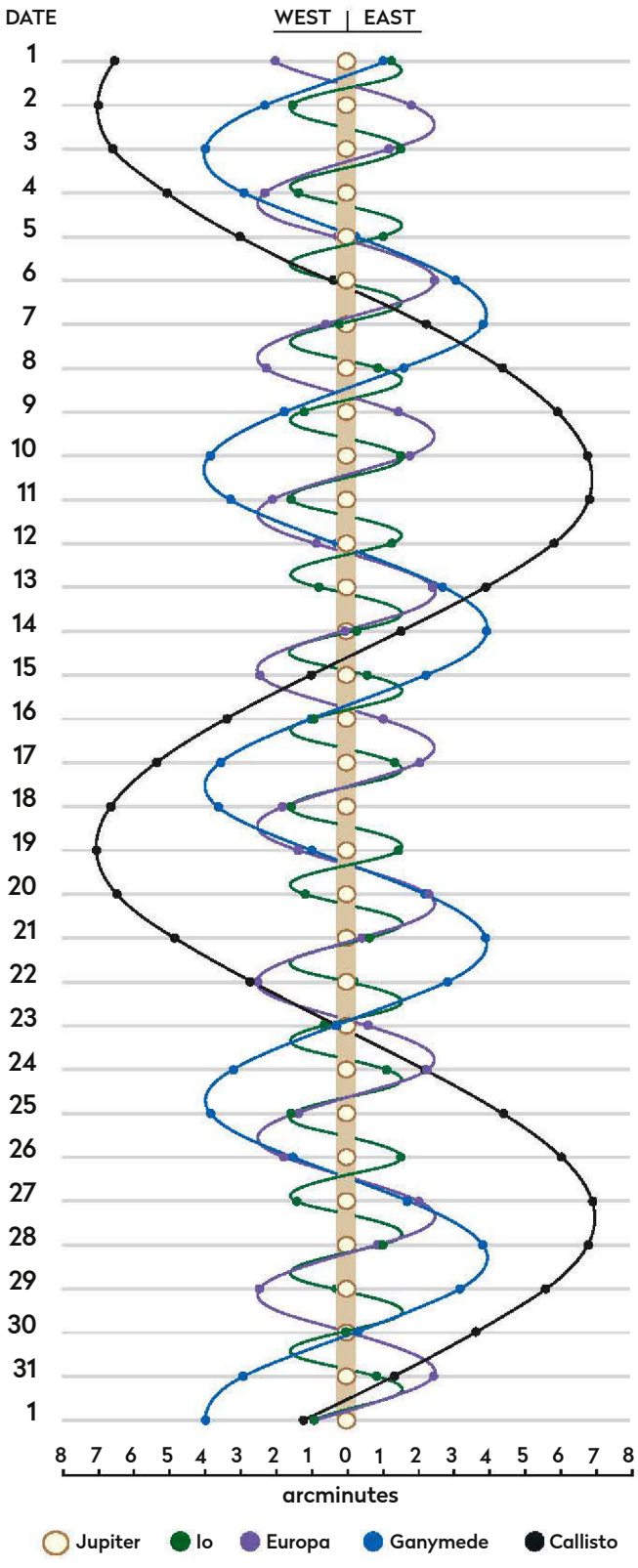
Not visible

Neptune is a morning object lost in the dawn twilight.

MORE **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: MAY

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically over the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – MAY

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Cricket — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

When to use this chart

1 May at 01:00 BST
15 May at 00:00 BST
31 May at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in May*

Date	Sunrise	Sunset
1 May 2023	05:36 BST	20:39 BST
11 May 2023	05:17 BST	20:57 BST
21 May 2023	05:01 BST	21:13 BST
31 May 2023	04:49 BST	21:27 BST

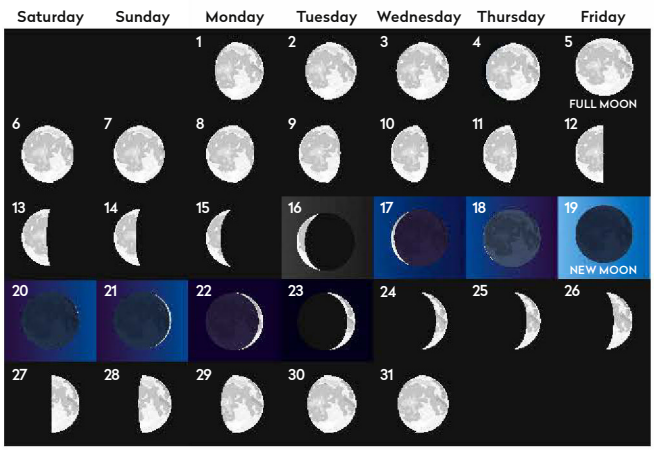
Moonrise in May*

Moonrise times

1 May 2023, 15:35 BST	17 May 2023, 04:18 BST
5 May 2023, 20:54 BST	21 May 2023, 05:34 BST
9 May 2023, 01:09 BST	25 May 2023, 09:32 BST
13 May 2023, 03:33 BST	29 May 2023, 14:30 BST

*Times correct for the centre of the UK

Lunar phases in May



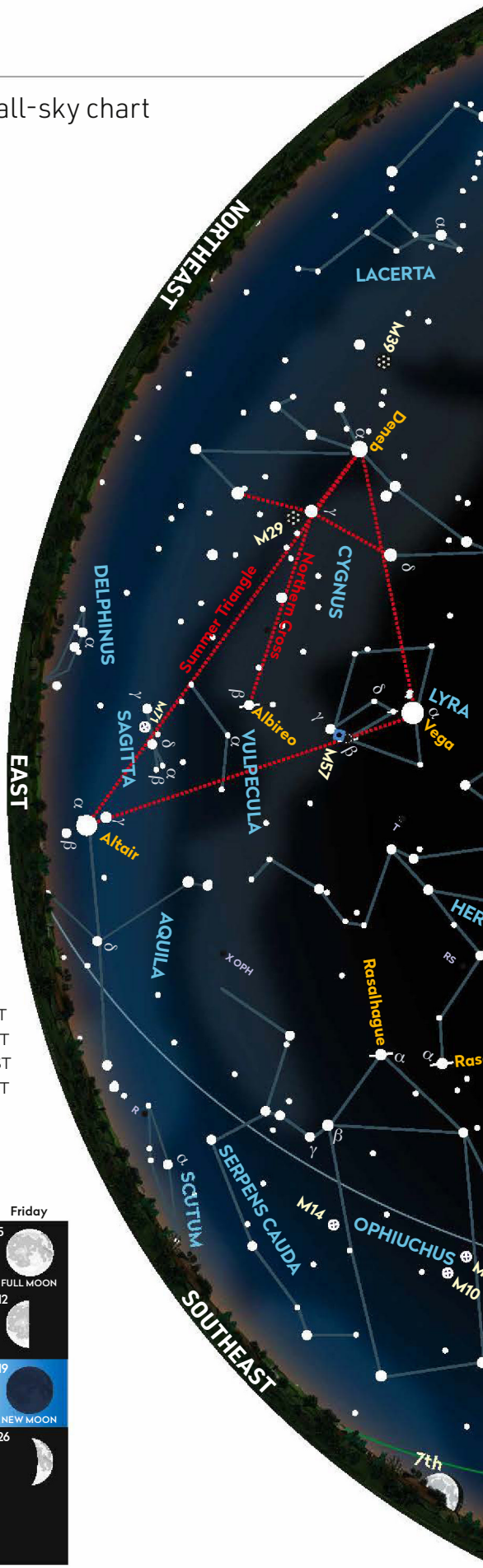


CHART: PETE LAWRENCE

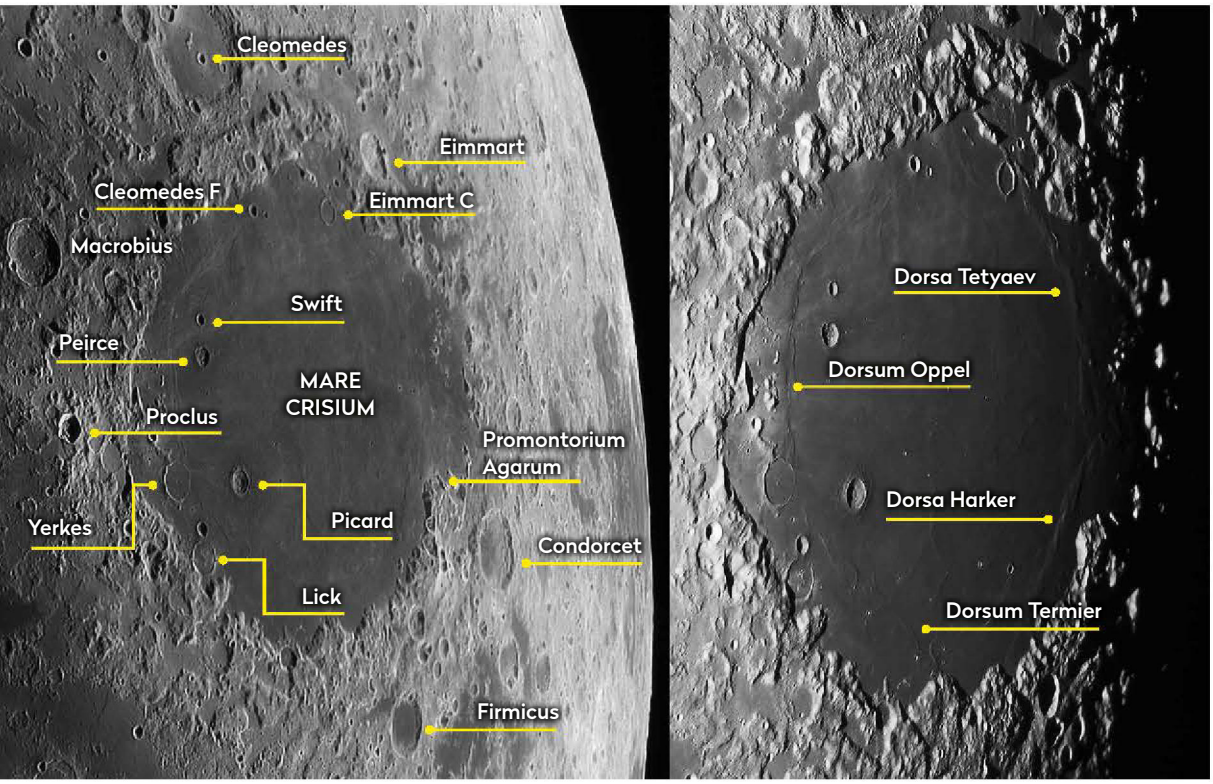
MORE **ONLINE**

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

MOONWATCH

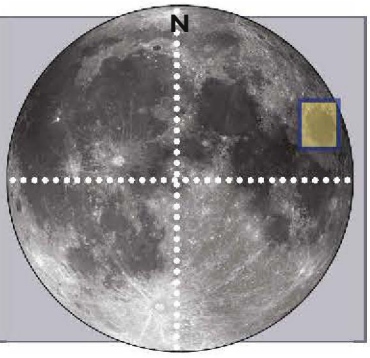
May's top lunar feature to observe



◀ Mare Crisium is full of features to explore (left) and has wrinkle ridges (right) lining its floor

Mare Crisium

Type: Lunar sea
Size: 420 x 600km
Longitude/latitude: 59.1° E, 16.2° N
Age: Older than 3.9 billion years
Best time to see: Three days after new Moon (22–24 May) or two days after full Moon (6–8 May)
Minimum equipment: 10x binoculars



As lunar seas go, **Mare Crisium**, the Sea of Crises, is unique in that it's isolated with no direct connection to any other sea on the lunar surface. From Earth it looks heavily foreshortened, appearing as an ellipse which you would think looks circular from above. However, it doesn't. If you were able to view it from above, its dark lava floor would measure 420km north to south and 600km east to west, the long axis of its oblate shape undoing some of the effect of foreshortening. Basically, if it were circular, it would appear substantially narrower from Earth.

It's an ancient sea over 3.9 billion years of age. It appears near the Moon's northeast limb and is a feature that rather defines the appearance of the Moon – a large, dark oval, easily visible to the naked eye. The most common views of the Moon are in the evening sky and this is when Mare Crisium is most prominent. Even with a casual glance, your brain registers the dark oval of this superb mare. This prominent feature is often the undoing of poorly researched movies, which either place it in the wrong position or don't show it at all in their evening view of the Moon.

The surface of the mare under direct illumination looks pretty flat. Only a handful of craters adorn the surface, confined to the edge regions. The most intrusive is 23km **Picard**, the centre of which is 98km from the nearest of Crisium's shores. Picard has an age range of 1.1–3.2 billion years, but looks quite youthful, with a sharp, almost circular rim and a sublime interior of concentric terraces leading to a flat floor. A low central mountain (perhaps hill is a better term) complex covers a large section of this floor.

Closer to the western shore are two superb examples of flooded craters: 36km **Yerkes** and 31km **Lick**. Yerkes has a complete rim surrounding a smooth lava-filled floor. The remains of its central mountain complex can be seen poking above the surface at the crater's centre. Lick's rim is open to the north, its floor occupied by a curious area of criss-crossing rilles.

North of Picard is 18km **Peirce**, another well-preserved, sharp-rimmed crater. Peirce and Picard have been described as the eyes of a hedgehog, Crisium the body and the elevated mountainous western mare border the mouth. It's worth taking a lot of time examining Crisium's edge as it contains numerous high-altitude cliffs, mountains and valleys. In addition, the apparently smooth floor is covered in beautiful examples of wrinkle ridges, best seen when the terminator is nearby.

Mare Crisium is a large, dark oval, easily visible to the naked eye

Just to the west of Crisium is a problem feature for lunar imaging, the 28km ray crater **Proclus**. The ejecta rays from this feature blast towards the east, creating a distinctive pattern across Mare Crisium. It's a problem because Proclus itself is very bright and causes issues with saturation level control when taking photos of the lunar surface.

PETE LAWRENCE X 3

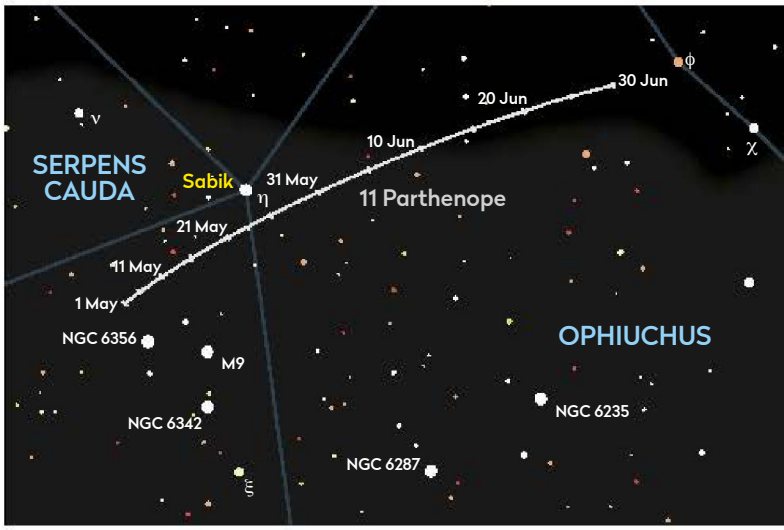
COMETS AND ASTEROIDS

Follow main belt asteroid 11 Parthenope as it tracks westward beneath Ophiuchus

The large, sparse constellation of Ophiuchus, the Serpent Bearer plays host to this month's featured asteroid, 11 Parthenope. Shining at mag. +10.4 at the start of May, Parthenope will brighten slightly through the month to peak around mag. +9.5 in early June. Opposition next occurs on 6 June when the asteroid will be below the main body of the serpent bearer, slightly south of a point roughly one-quarter the way along an imaginary line between Sabik (Eta (η) Ophiuchi) and Phi (ϕ) Ophiuchi.

During May, Parthenope's track starts further to the east, approximately 1.3° north of the mag. +8.4 globular cluster, NGC 6356. It then travels west, in the gentlest of north-arcing curves to pass 0.8° south of Sabik between 24 and 26 May. At this time it will be around mag. +9.7, close to peak brightness.

Unless you have large binoculars, a small telescope is the minimum instrument required to see Parthenope, and the best technique to record it is the classic blink method. Here you record the starfield you expect Parthenope to be passing through, noting as many stars as you can see. A photograph makes this easy, but sketching works too. Make multiple recordings over several clear nights and compare the results. If one of the stars appears to move, that's likely to be Parthenope. At the end of June, it will be 1.5° to the east of mag. +4.3 Phi Ophiuchi.



▲ **Starting north of NGC 6356, Parthenope will pass under Sabik**

Parthenope is a main belt asteroid, the orbit of which takes it out as far as 2.7 AU from the Sun and in as close as 2.2 AU. Its orbital period is 3.84 years, the asteroid rotating on its axis once every 13.7 hours. It's an S-type asteroid, which means it's siliceous or stoney. This type accounts for 17 per cent of all known asteroids, a class which tends to be fairly reflective, with average albedos (reflectivity) around 20 per cent.

STAR OF THE MONTH

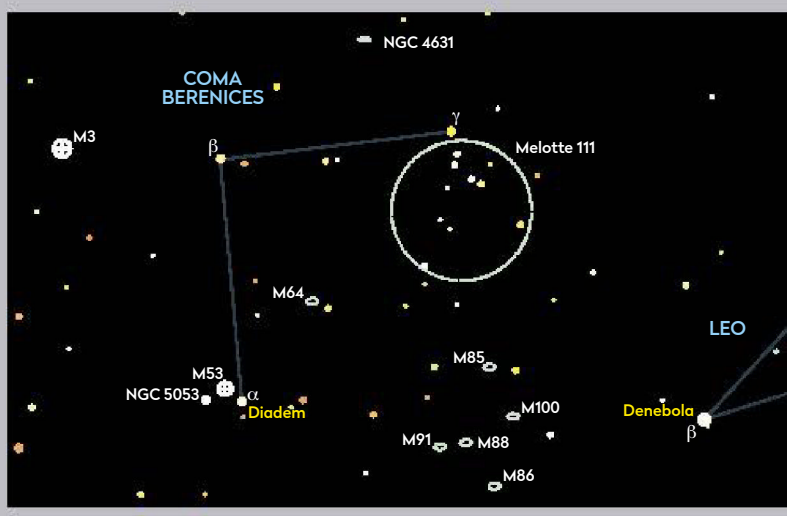
Diadem, the bright trinket in a queen's hair

Diadem (Alpha (α) Comae Berenices) is the principal star of Coma Berenices, Queen Berenice's Hair. The hair in question belonged to Queen Berenice II of Egypt, who pledged it to the gods in exchange for the safe return of her husband, King Ptolemy III Euergetes. The star is located in the southeast corner of the constellation, 15° to the west of the bright, orange giant, Arcturus (Alpha (α) Bootis). At mag. +4.3, Diadem is the second-brightest star in Coma Berenices after Beta (β), located 10.4° to the north.

Coma Berenices is characterised by the large, triangular-shaped open cluster, Melotte 111, which is located further to the west. It's the faint cluster stars that represent the queen's hair. Diadem and Beta Comae Berenices are not part of the cluster.

Diadem is derived from the Arabic meaning 'the braid'. It's a binary star consisting of two equally bright components of magnitudes +5.1. The orbital period for the binary is relatively short at 25.87 years. From Earth, the maximum separation we see between both stars is 0.7 arcseconds. When closest, they appear inseparable, the inclination of their orbital plane being just one-tenth of a degree. The last close passage occurred in 2001, which means the pair are currently closing for another. As well as sharing the same brightness, the two binary components of Diadem are F5 dwarfs, both shining with a warm, yellowish hue.

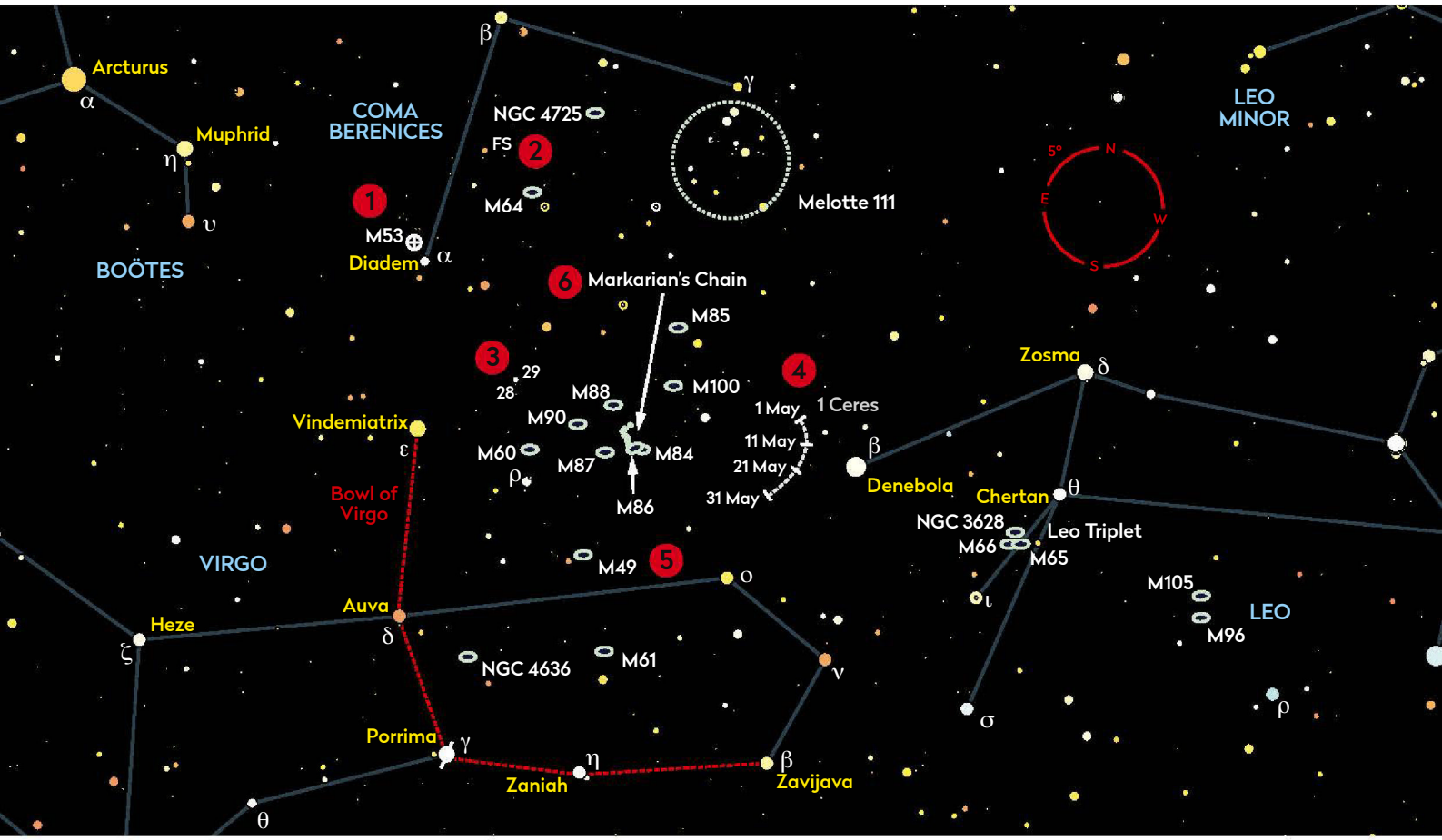
▼ **The Diadem system 58.1 lightyears from Earth, with globular clusters M53 and NGC 5053 sitting nearby**



BINOCULAR TOUR

With Steve Tonkin

Variety is the spice of life as we hunt stars, globulars, galaxies and more near Virgo



1. M53

10x 50 A degree northeast of mag. +4.3 Diadem (Alpha (α) Comae Berenices), you'll find a small misty patch which appears to grow in size and brightness if you centre it in the field of view then avert your gaze back to Diadem. The apparent changes, which are typical of globular clusters, demonstrate the difference between direct and averted vision. Practice this technique; you'll need it later when we seek out the galaxies in Markarian's Chain. ☐ **SEEN IT**

2. FS Comae

10x 50 Navigate to a point half-way between Diadem and mag. +4.2 Beta (β) Comae Berenices, then another degree to the west to an orange star, FS Comae, shining somewhere around mag. +6. The magnitude of this semi-regular variable star varies between mag. +6.1 and + 5.3, with a period of 55–58 days. Analysis of the star's spectrum reveals variations in radial velocity of the star's surface, which indicates that its variability is due to pulsations in size. ☐ **SEEN IT**

3. 28 &29 Comae

10x 50 Head 5° northwest of mag. +2.8 Vindemiatrix (Epsilon (ε) Virginis) to a pair of white stars separated by half a degree and orientated roughly north–south. The southerly one is mag. +6.4 28 Comae, brightest of a little parallelogram of stars. Mag. + 5.7 29 Comae is the brightest of a triple star group. The brighter (mag. +8.6) companion is 5 arcminutes back towards 28 Comae, and the fainter (mag. +9.9) one is an arcminute closer. ☐ **SEEN IT**

4. Ceres

10x 50 Ceres was discovered by Guiseppe Piazzi on the first day of the 19th century and is the only dwarf planet visible in standard binoculars. It fades from mag. +7.8 to mag. +8.4 during the month, but should be easiest to detect around mid-month when the Moon is out of the way and it is 2.2° east of mag. +2.1 Denebola (Beta (β) Leonis). ☐ **SEEN IT**

5. M49

15x 70 Locate mag. +4.9 Rho (ρ) Virginis and place it on the northeast of your field of view. On the opposite side you should find a pair of sixth-magnitude stars, a little more than a degree apart and orientated southeast–northwest. M49 is the small, slightly oval patch of light between these two. Use averted vision to see how many more galaxies you can detect in this region of sky. ☐ **SEEN IT**

6. Markarian's Chain

15x 70 This chain of galaxies, which you may already have detected north of M49, lies almost exactly half way between Vindemiatrix and Denebola. Starting with M84 and M86, you should be able to identify at least the seven brightest galaxies in the chain. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 2

THE SKY GUIDE CHALLENGE

This one's tricky: try to photograph Jupiter during its daytime meeting with the Moon

There's no denying that the occultation or close pass (depending on your location) event with the Moon and Jupiter on 17 May will be hard to observe as it takes place during daylight hours. However, given clear skies, Jupiter can definitely be seen in a blue sky, either using binoculars or through a telescope. Your challenge this month is to go one further and try to photograph the planet.

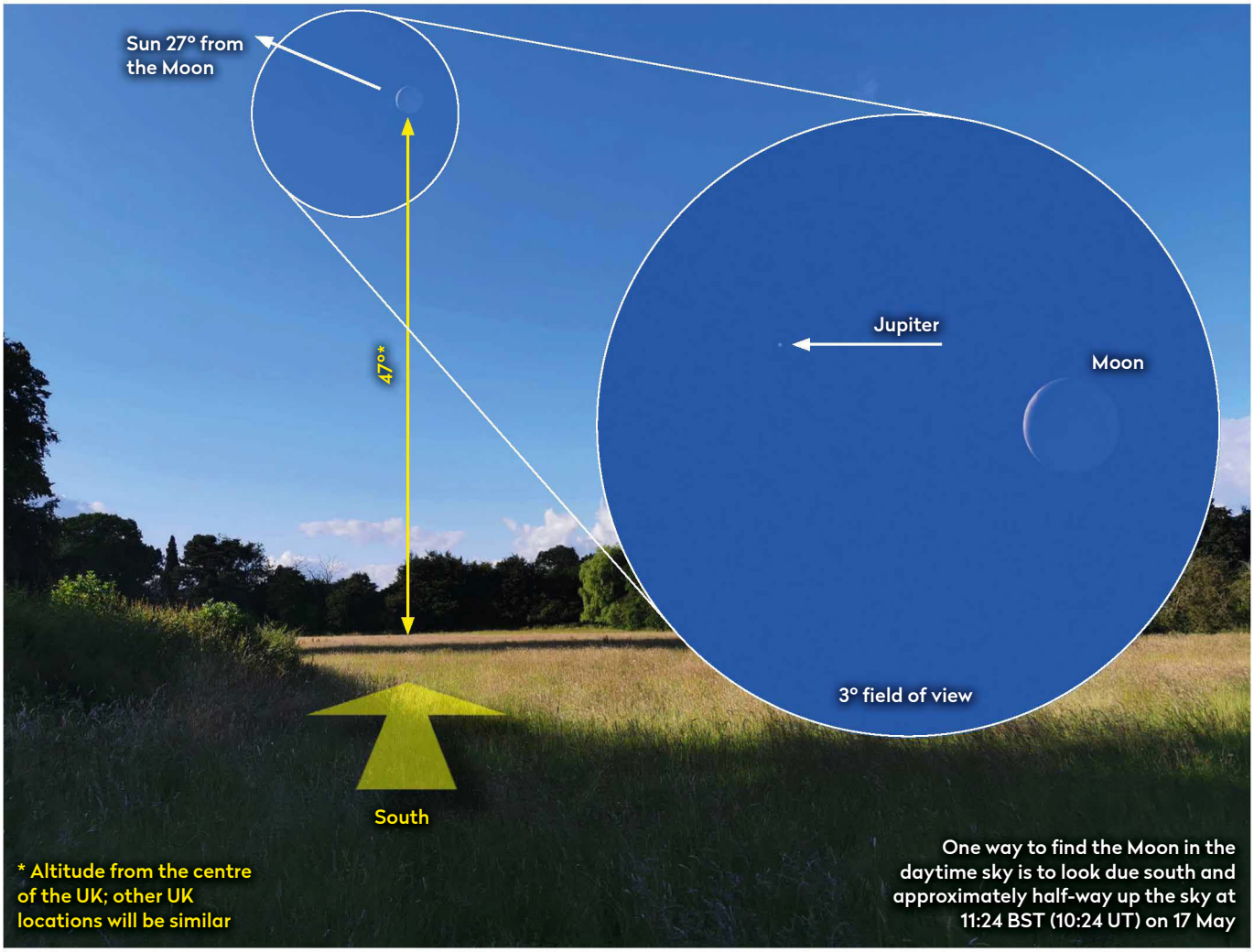
A daylight sky will greatly reduce contrast in the visible spectrum, but as long as you can locate Jupiter, switching to an infrared pass filter combined with an infrared-sensitive camera should make it possible to improve the view. If you don't have such equipment, don't worry. It's still possible to get an unfiltered shot of the planet using a DSLR, but you may need to work a bit harder to separate its dim, low-contrast disc from the sky.

The event on 17 May will have the benefit of the Moon being nearby, but even this may be challenging. With a waning crescent phase at 7% illumination, the Moon too will appear quite indistinct against the blue sky.

There are various ways to locate the Moon. The easiest is to catch it earlier as it rises in darker skies. This is around 04:30 BST (03:30 UT) from the centre of the UK. Using a polar-aligned equatorial telescope mount, you'll need to set the drive to its lunar rate, then centre the view on the Moon's disc. If you're unsure about the precision of the polar alignment, you'll need to schedule in periodic checks.

Another method is to estimate where the Moon will be at a set time and try to locate it that way. At 11:24 BST (10:24 UT), the Moon will appear at an altitude around 47° due south. This should give you enough information to get into the general area. As ever, take great care when looking as the Sun will be up and relatively close by. Observing from safely inside the shadow of a building so the Sun can't be seen is a good strategy to keep safe.

Once you have managed to locate the Moon, Jupiter should be a lot easier to find. Just be prepared for its disc to be extremely low in contrast, almost a ghost of its nighttime self. Use the Moon as your focus target, taking care to focus as accurately as possible. The sky can be bright, but don't allow it to over-expose or you won't be able to recover the planet. Once taken, adjust the levels of the image using your favourite image-editing program, darkening the sky with the mid-point slider and tweaking to bring out weak Jupiter at its best.



One way to find the Moon in the daytime sky is to look due south and approximately half-way up the sky at 11:24 BST (10:24 UT) on 17 May

DEEP-SKY TOUR

Everybody knows the Plough, but can you find all six Messier objects in the surrounding field?

1 M101

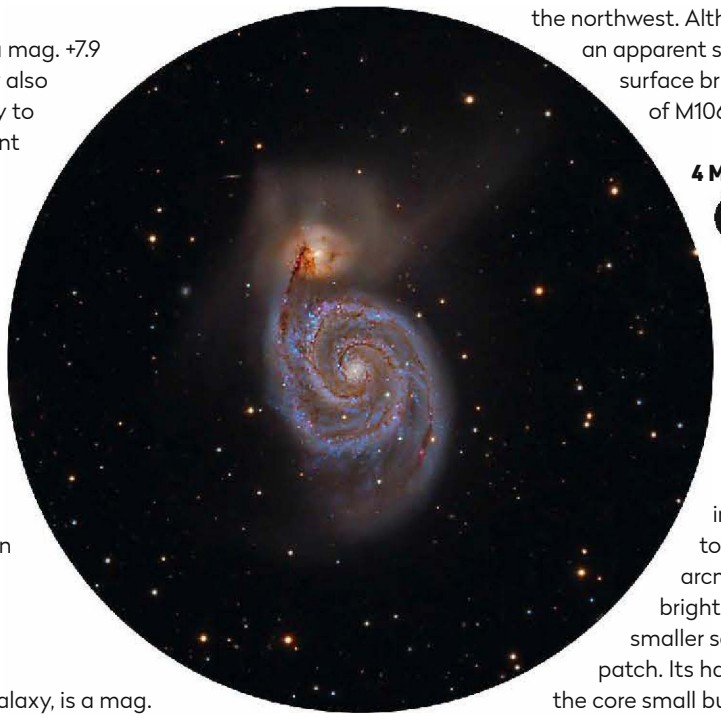
We start with M101, a mag. +7.9 face-on spiral galaxy also known as the Pinwheel. It's easy to find, marking the northeast point of an equilateral triangle with Mizar (Zeta (ζ) Ursae Majoris) and Alkaid (Eta (η) Ursae Majoris). M101 appears large, 20 x 15 arcminutes through a 150mm scope, which gives it a low surface brightness, but it remains relatively easy to see. A small scope shows a mottled object with uneven brightness, definitely oval with a small, central nucleus. Larger instruments give more definition to the spiral arms, revealing distinct star knots. ☐ **SEEN IT**

2 M51

M51, the Whirlpool Galaxy, is a mag. +8.4 spiral galaxy which, like M101, is presented face-on to us. However, M51 is smaller than M101 at 11 x 7 arcminutes and this gives it higher surface brightness. It lies within Canes Venatici, 3.6° southwest of Alkaid. Locate it by imagining it as the southwest point of an isosceles triangle with Alkaid and mag. +4.7 24 Canum Venaticorum. Smaller instruments show a mottled halo surrounding a brighter core. The galaxy has an interacting companion of apparently similar surface brightness but smaller: mag. +9.6, 5 x 4 arcminute NGC 5195. A 250mm or larger scope shows the tightly wound spiral arms of M51 well. ☐ **SEEN IT**

3 M106

Next is galaxy M106, 12° west of M51 and roughly mid-way between Phecda (Gamma (γ) Ursae Majoris) and Chara (Beta (β) Canum Venaticorum). It's a bright and large spiral galaxy, shining at mag. +8.4 with an apparent size of 19 x 8 arcminutes. Like M51, M106 lies in Canes Venatici. A 150mm scope shows it well, a mottled, granular object with a bright core region surrounding a bright nucleus. Larger instruments help pick out the tight spiral arms within the core. They appear somewhat lop-sided, the arm to the northeast appearing brighter. The smaller galaxy, NGC 4248, is located 13 arcminutes to the northwest. Although listed as mag. +12.6, with an apparent size of 3 x 1.2 arcminutes, its surface brightness isn't dissimilar to that of M106. ☐ **SEEN IT**



▲ **The magnificent M51, the Whirlpool Galaxy, and its smaller companion NGC 5195 never fail to impress**

4 M109

M109 returns us to Ursa Major. This mag. +9.8 barred spiral is really easy to locate. Simply extend the line from Merak (Beta (β) Ursae Majoris) through Phecda, extending it for 39 arcminutes; using a low-power eyepiece, Phecda and M109 will probably appear in the same field of view. With a total apparent size of 7.6 x 4.9 arcminutes, M109's surface brightness can be a struggle for smaller scopes which show it as a hazy patch. Its halo appears indistinct and faint, the core small but nicely concentrated. The galaxy's central bar and tightly wound arms can be seen with larger instruments with powers of around 150–250x revealing the best views. ☐ **SEEN IT**

5 M97

M97 is a planetary nebula with a reputation for being one of the harder objects in the Messier catalogue to see, mainly because of its low surface brightness. It's listed at mag. +9.9 and has apparent dimensions of 3.4 x 3.3 arcminutes. Find it by heading one-quarter the distance from Merak towards Phercad, looking 0.8° south-southwest (perpendicular to the Merak–Phercad line) of this point. A 150mm scope shows a featureless circular glow. A 250mm instrument and averted vision may show two darker patches within the glow. A 300mm scope shows the 50-arcsecond patches better, but they are still far from easy. They have been likened to two eyes looking back at you, hence its informal name, the Owl Nebula. ☐ **SEEN IT**

6 M108

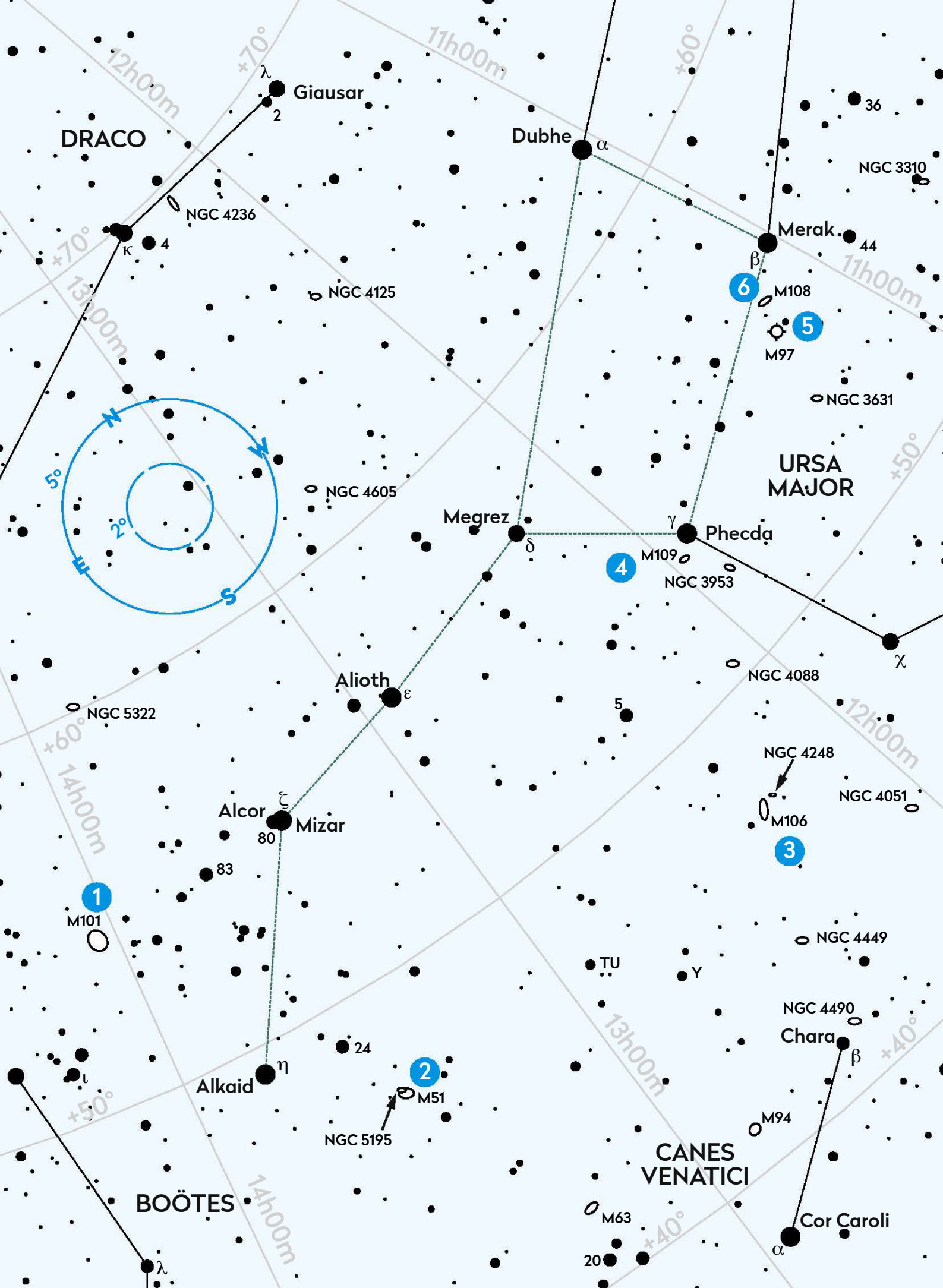
You may have passed over our final target, the edge-on spiral galaxy M10, on your way to M97. To locate mag. +10.0 M108, head 1.5° from Merak along the Merak–Phecda line, then 0.3° south-southwest (perpendicular to the line). This can be a tricky object in small instruments, a 150mm scope revealing an elongated glow of 8 x 1.5 arcminutes. At 100x power it shows a clumpy, broken appearance, but seems to lack a core. Larger apertures brighten the galaxy, but fail to reveal anything more than the elongated, unevenly-lit halo hinted at by a smaller scope. ☐ **SEEN IT**

DIETER BEER/PATRICK HOCHLEITNER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions


DRACO
URSA MAJOR
BOÖTES
CANES VENATICI
Giausar
Dubhe
Merak
Megrez
Phecda
Alioth
Alcor
Mizar
Alkaid
Chara
Cor Caroli
NGC 4236
NGC 4125
NGC 4605
NGC 5322
NGC 3310
NGC 3631
NGC 3953
NGC 4088
NGC 4248
NGC 4051
NGC 4449
NGC 4490
NGC 5195
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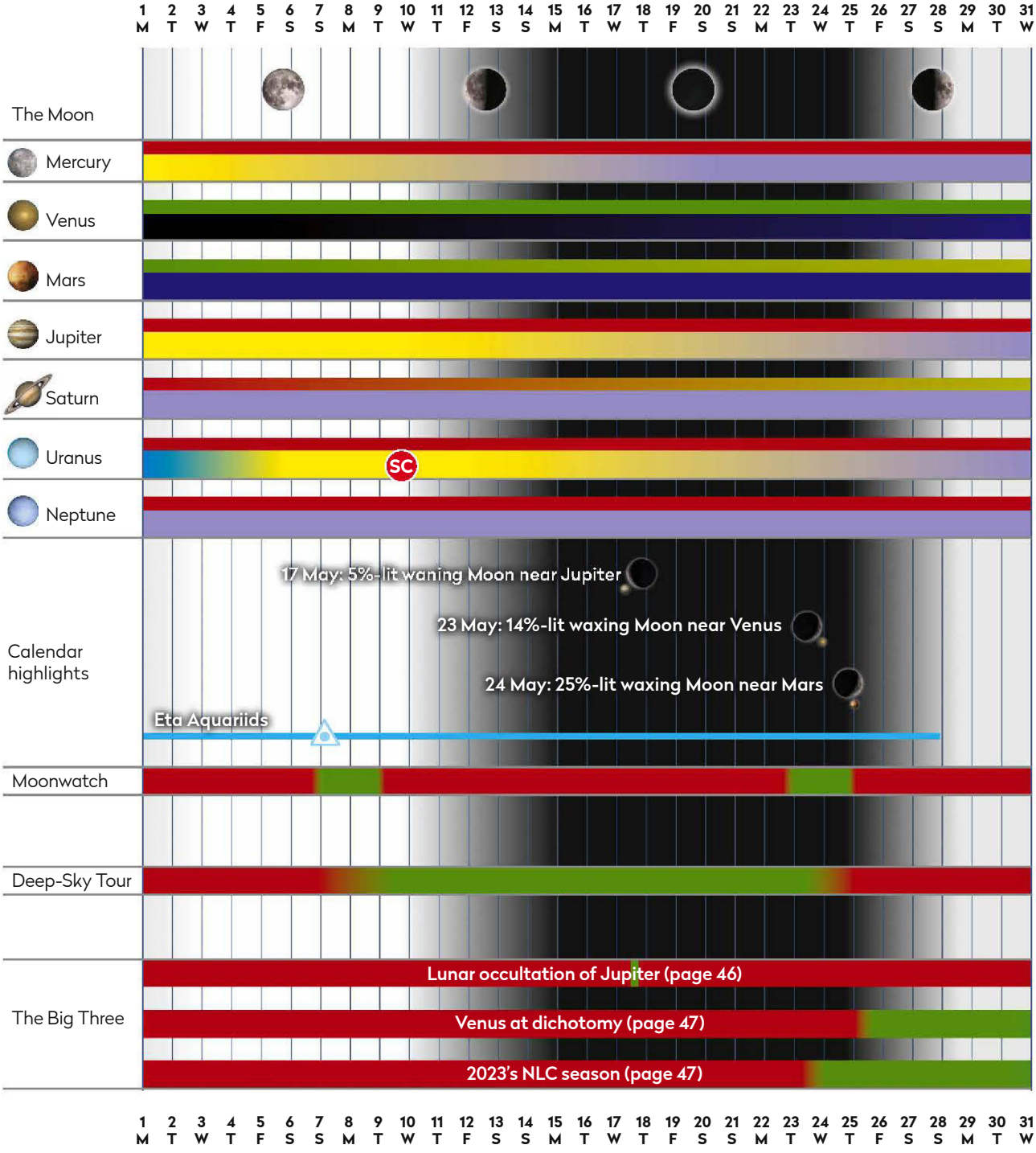
AT A GLANCE

How the Sky Guide events will appear in May



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

- IC — Inferior conjunction (Mercury & Venus only)
- SC — Superior conjunction
- OP — Planet at opposition
- Meteor radiant peak
- Planets in conjunction

- Full Moon
- First quarter
- Last quarter
- New Moon

CHART BY PETE LAWRENCE

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Darkness on the moors

In search of true darkness and skies that sparkle, **Jamie Carter** visits Yorkshire, home of the UK's newest International Dark Sky Reserves

Tonight there's mist on the way to the moors. It creeps through the valley and blots out everything but Venus. But as the minibus climbs up the Sutton Bank escarpment, it begins to clear. By the time we arrive at the North York Moors International Dark Sky Reserve, we're high above the valley mist among heather moorland, low shrubs and stumpy trees. Above us is a big sky with only thin wisps of cloud between the bright stars. The open clusters within Auriga are naked-eye bright and so are the faint suns of Gemini, Taurus and Ursa Minor, all now so elusive from our towns and cities.

"Does anyone know, what is the furthest thing it's possible to see with the naked eye?" says astronomer Richard Darn, our host for the evening. "The Moon?" says a voice from the dark. "A nebula?" asks another. The Andromeda Galaxy, 2.5 million lightyears from Earth, is soon picked out with a green laser. It's waiting in the crosshairs of a Takahashi refractor for all to inspect. It's an exciting moment for many. In its wake comes the equally crowd-pleasing Pleiades, the Orion Nebula, the M81 and M82 galaxies, double star Almach, and a waning comet, C/2022 E3. The views are delivered crisply and quickly, but some guests seem happy just to stare at a 'blanket of stars' they've heard much about but rarely seen.

Nightseeing trip

This is a crowd mostly taking their first steps in navigating the night sky and they've come from all over the UK – from Liverpool, Essex, Bournemouth and Cardiff – for the first of the North York Moors' two annual Dark Skies Festivals. This particular event during the festival is organised by The Grand Hotel in nearby York as a 'dark skies package' that includes dinner, stargazing and breakfast. Oh, and a flask of hot chocolate to take up to Sutton Bank's Star Hub, a purpose-built stargazing facility with a tastefully red-lit courtyard for telescopes and an indoor area to warm up. This is amateur (g)astronomy at its best.

"There's so much demand for these events now," Darn says to me as we pack away the telescopes and binoculars later. "I love doing them. People have travelled from so far to be here and for many of them it's such an adventure just to walk out into a dark night." ▶

TONY MARSH

The Yorkshire Dales and North York Moors National Parks both recently became International Dark Sky Reserves

The Northern Lights put on a show over Sandsend, north of Whitby, on the North York Moors coast

▶ It helps that the North York Moors is one of the driest upland areas in the UK, which frequently means clear skies. Although it's one of three Milky Way-class Dark Sky Discovery Sites in the North York Moors, Sutton Bank isn't in the darkest 'core zone' in the national park. That's not really the point of events like these. "For most people here tonight, this is the darkest sky they've ever seen and I think that's really important – it's about accessibility," says Darn.

The skies have been getting darker in this part of the north of England for a few years. Both the North York Moors National Park and the nearby Yorkshire Dales National Park became International Dark Sky Reserves in December 2020 and, at 3,615 square kilometres, together form the largest region of protected night skies in the UK. The parks' light pollution readings are as low as 21.6 and 21.7 on the Bortle scale, respectively. "It wasn't a joint application, just a simultaneous designation, but we work really closely together both on the applications and on our Dark Skies Festivals," says Mike Hawtin, dark skies officer at the North York Moors National Park.

Locals help fight the light

Such is the rampant march of light pollution that getting and keeping Dark Sky status is not easy. The applications to the International Dark-Sky Association took about three years. "We had to monitor light levels at over 100 different sites and submit our dark skies readings – and we must do an annual report to prove that our skies continue to be dark," says Hannah Kay, dark sky project manager at the adjacent Yorkshire Dales National Park. Grants are available for local businesses and farms in both parks to install dark-sky-friendly lighting. The message to residents and visiting stargazers alike is simple, but can make a huge difference to keeping the skies dark: "Have your lighting pointed down, use timers, use motion-sensor lighting where possible, and use warm colours," says Kay.

▲ The Milky Way over Young Ralph Cross atop the remote Blakey Ridge, North York Moors

At its heart, the dark-sky designation is about taking practical steps to stop developments that have very poor lighting. It's an easier sell than you might think. "I've done 100 site visits and presentations to parish councils, farmers' groups and landowners. I've had zero pushback," says Hawtin. "I just explain that it's not about banning all light, but using it sensitively, responsibly and sympathetically."

Both parks have targeted their darkest 'core zones' first because that's where new dark-sky-friendly ▶

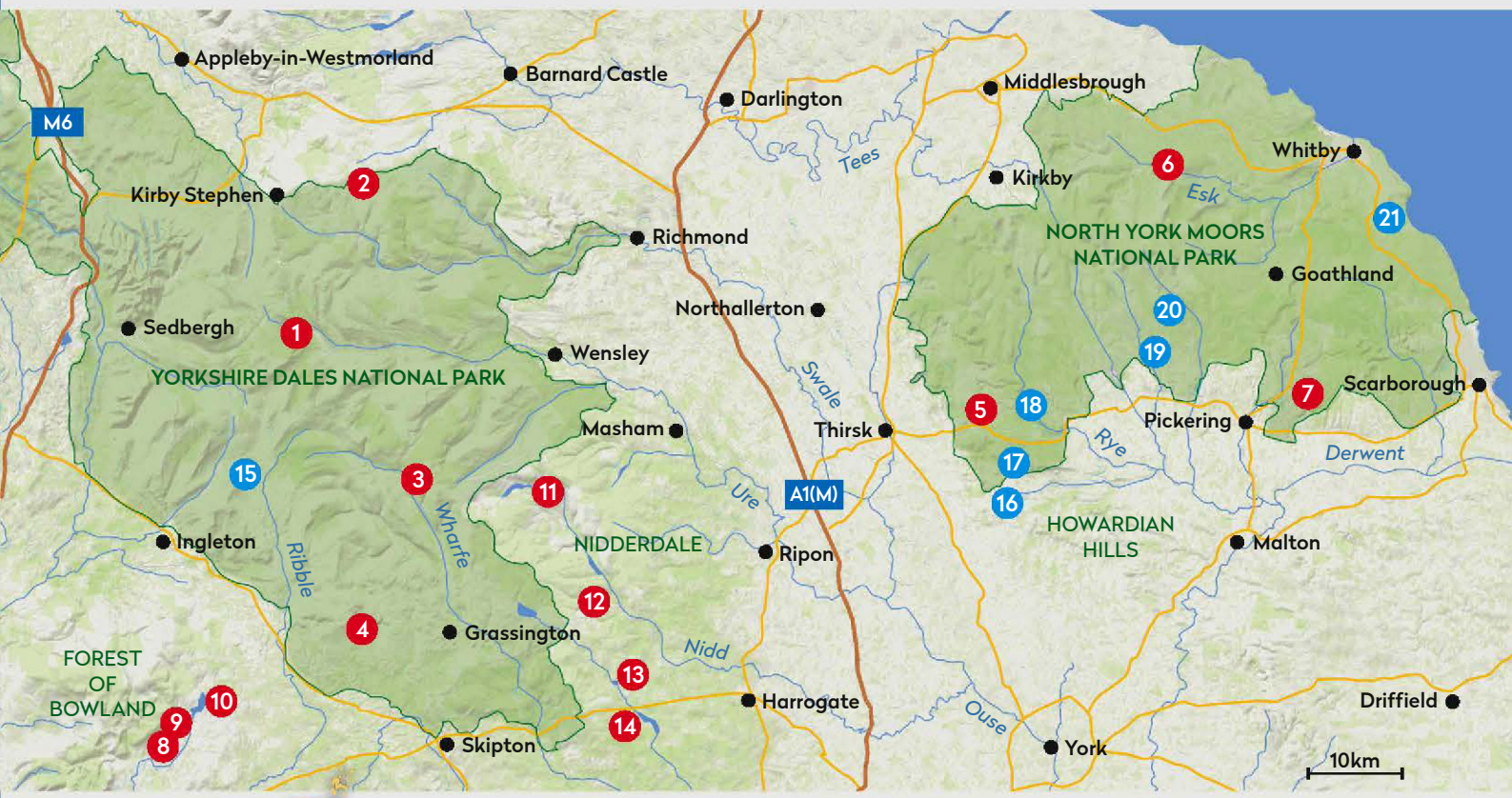
STEVE BELL X 2, JAMIE CARTER, MAP BY PAUL WOOTTON

First-class views of Orion from the Star Hub at Sutton Bank, North York Moors

Stargazing in the Moors and Dales of Yorkshire

Both parks offer a wealth of places to enjoy the wonders of the night sky

There are several Dark Sky Discovery Sites throughout the two parks which offer not only a place to get away from light pollution, but also good sightlines and public access. For an excellent photo opportunity, several spots have wonderful foregrounds to offset your skyscapes. The coast along the North York Moors has clear views of the northern horizon and occasionally the Northern Lights. Byland and Rievaulx Abbey offer beautiful foregrounds, while the fish pond outside Newburgh Priory is a great location for reflections shots. The Dales, meanwhile, are home to Ribblehead Viaduct, an iconic 24-arch Victorian structure that can be photographed with the Milky Way behind it. For the darkest skies, however, aim for the core zone in the heart of each park. Finally, just outside the parks are more Dark Sky Discovery Sites in two Areas of Outstanding Natural Beauty: five in Lancashire's Forest of Bowland (three shown below) and four in Nidderdale.



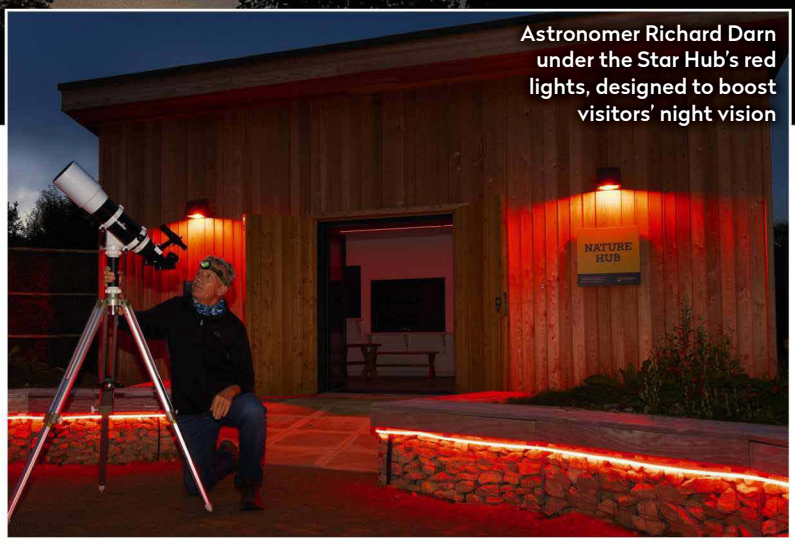
Dark Sky Discovery Sites

1 Hawes National Park Visitor Centre
2 Tan Hill Inn
3 Buckden National Park Car Park
4 Malham National Park Visitor Centre
5 Star Hub, Sutton Bank National Park Centre
6 The Moors National Park Centre
7 Dalby Forest Visitor Centre
8 Clerk Laithe Lodge guest house
9 Slaidburn village car park
10 Gisburn Forest Hub
11 Scar House Reservoir
12 Toft Gate Lime Kiln
13 Thruscross Reservoir
14 Fewston Reservoir

Photo opportunity sites

15 Ribblehead Viaduct
16 Newburgh Priory
17 Byland Abbey
18 Rievaulx Abbey
19 Hutton-le-Hole village
20 Rosedale Chimney Bank
21 Robin Hood's Bay

"Star followed star through boundless regions" as local Emily Brontë wrote of the pristine skies above the moors



Astronomer Richard Darn under the Star Hub's red lights, designed to boost visitors' night vision

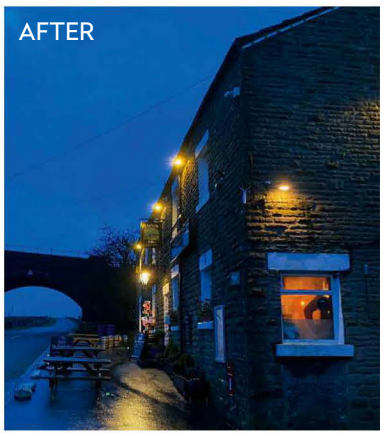
▶ lighting can make the most difference. However, there's also a dark-sky-friendly business scheme that incentivises local people to keep the lights down low. "About 30 local businesses have signed up and can specifically promote themselves as dark-sky-friendly," says Kay. "So if it's a bed and breakfast it will have dark-sky-friendly lighting, telescopes, binoculars and blankets."

Another pillar of any park's dark-sky status is outreach, something both of these regions excel in. The North York Moors and the Yorkshire Dales both host some of the UK's largest and most successful dark-sky festivals. Staged in the same weeks each February and October – the next will be the Dark Skies Fringe Festival, from 27 October to 5 November – they include so much more than stargazing, including runs, zip wires, kayaking and biking at night to astrophotography workshops, stargazing safaris and night walks. In 2022, there were 44 different events involving over 2,400 people. "We've had events where people go out running on the moors or cycling in the dark and they're often attended by people who don't usually get to see such dark skies," says Kay. "We reach out to people to come and see our dark skies because it's something they will never see if they live in Leeds or Bradford."

Businesses get on board

The success of the festivals and dark-sky status is beginning to nurture an emerging dark-sky economy. "We initially started holding our events at Dalby Forest during October 2022's Dark Skies Fringe Festival," says Nicole Carr at AstroDog, a small astronomy and astrophotography business based on the Yorkshire coast run by Nicole, partner Simon Scott – and their dog Luna. "They were very popular and we welcomed many wonderful guests to our stargazing hub in Dalby to gaze at and learn about the night sky." AstroDog now holds events almost every night throughout the festivals, as well as throughout the year.

Yorkshire might be having its own dark skies moment, but those behind it want more than just protected skies within national park boundaries. "I don't like the idea that if you want to see the stars you have to go into these designated areas, yet



▲ A few dark-sky-friendly measures help cut the glare from this inn near the famous Ribblehead Viaduct

RUSS NORMAN PHOTOGRAPHY, STEVE BELL, NORTH YORK MOORS AND YORKSHIRE DALES NATIONAL PARKS, THE GRAND/ YORK HOTE, EASTERSIDE FARM B&B, FOX AND HOUNDS, WEST CAWTHORNE CABINS, OLD DAIRY B&B, NETHERGILL FARM

Where to stay under Yorkshire's dark skies

Whatever your budget, there's somewhere to suit your stargazing needs

The Grand Hotel, York
This luxury hotel in York hosts Dark Skies Experience packages in autumn and winter, including dinner, a two-hour stargazing session and a one-night stay with breakfast. £405 for two/£315 for one. **www.thegrandyork.co.uk • 01904 380038 • yourstay@thegrandyork.co.uk**

Easterside Farm B&B, Hawnby
Just outside the village of Hawnby in the North York Moors National Park, this is a 15-minute drive from the Star Hub at Sutton Bank and an ideal base for your stargazing trip. £110 per night. **www.eastersidefarm.co.uk • 01439 798277 • info@eastersidefarm.co.uk**

Fox and Hounds Inn, Ainthorpe
Torches, binoculars and night-sky maps are on hand at this 16th-century inn in the North York Moors National Park with a traditional pub atmosphere. B&B rooms (£109) or insulated glamping pods (£69). **www.foxandhoundsainthorpe.com • 01287 660218 • info@foxandhoundsainthorpe.com**

West Cawthorne cabins, Pickering
Stylish self-catering A-frame cabins with decks high on a hill within a re-wilded landscape in the North York Moors National Park, with binoculars provided. There's a two-night minimum stay (£320). **www.northyorkshirehideaways.com • info@westcawthorne.com**

Old Dairy B&B, Richmond
This B&B is run by keen astronomer Paul Clark, who happily gives advice to guests. Located in tiny Low Row, it boasts some of the darkest skies in the Yorkshire Dales National Park (£105 per night). **airbnb.com/h/olddairylowrow • olddairylowrow@gmail.com**

Nethergill Farm, Oughtershaw
This eco-farm in the Yorkshire Dales National Park is perfect for stargazing and birdwatching, including a field centre with telescopes and binoculars. Self-catering for four people (£480 for three nights). **www.nethergill.co.uk • 01756 380581 • info@nethergill.co.uk**

everywhere else you're free to do whatever you like with light," says Darn. "National parks are not an excuse for everywhere else to be overwhelmed by light pollution – they are a model that proves that reducing it everywhere is not rocket science."

The North York Moors and Yorkshire Dales must and do engage with surrounding authorities in an effort to keep their dark-sky status. "If we allow development around us to go unchecked then that shrinks our patch," says Hawtin. The classic example is the Peak District National Park, which is surrounded by Manchester, Leeds and Sheffield and would struggle to get any kind of dark-sky status.

Is it too late for them and all the UK's urban areas? "You could say that it's a lost battle in towns and cities, but there is one thing about light pollution that keeps me optimistic," says Hawtin. "It's all solvable at the flick of a switch."

Jamie Carter is a science and astronomy writer and author of *A Stargazing Program for Beginners: A Pocket Field Guide*

The shortlived Skylab floats 440km above Earth with the hastily fitted golden parasol, used to keep soaring temperatures at bay, clearly visible

▲ Left to right: Jack Lousma (SL-3, the second crew), Ed Gibson and Gerald Carr (SL-4, the fourth and final crew) enjoy all the space on board Skylab

The story of SKYLAB

Fifty years on from its launch, **Jane Green** takes a look back at the troubles and triumphs of the USA's trailblazing space station

Skylab 1 was America's first long-duration orbiting laboratory. Crewed between May 1973 and February 1974, it was the 'great uncle' of Mir and the International Space Station, engineered from the shell of a redundant rocket stage (part of an earlier epic space programme). Transformed with additional modules and structures, Skylab became an unmitigated success. With humans now scheduled to return to the Moon in the near future, it's time to celebrate this venerable one-of-a-kind space station.

Skylab was ultimately the result of Cold War political hostility between the Soviet Union and the United States. When Russia launched its first artificial satellite, Sputnik, in October 1957 – aboard an R-7 rocket designed by Russian Sergei Korolev – the United States was worried. The race between these two superpowers for the domination of space began in earnest. Their next target? The Moon.

Having already sent astronauts into orbit during Project Gemini, on 20 July 1969 the Moon race was won by the USA when Apollo 11's Neil Armstrong and Buzz Aldrin took humankind's first footsteps in the lunar dust. The next goal was to achieve a lasting presence in space: Skylab.

Rocket recycling

With the Apollo programme in the 1970s cut short, NASA began the Apollo Applications Program, its remit to adapt redundant hardware and systems developed for the lunar landing. Needing to keep his staff employed, famed Apollo rocket engineer and head of NASA's Marshall Flight Center, Wernher von Braun, advocated launching an orbiting workshop using two-stage Saturn IB rockets. The hydrogen tank of the S-IVB stage would have ample room for what would be known as a 'wet' workshop. It could be launched loaded with liquid oxygen and liquid ▶

NASA X-4

A Saturn V S-IVB stage, modified to create an orbital workshop – later renamed Skylab – is unloaded at Redstone airfield, Alabama, 1968

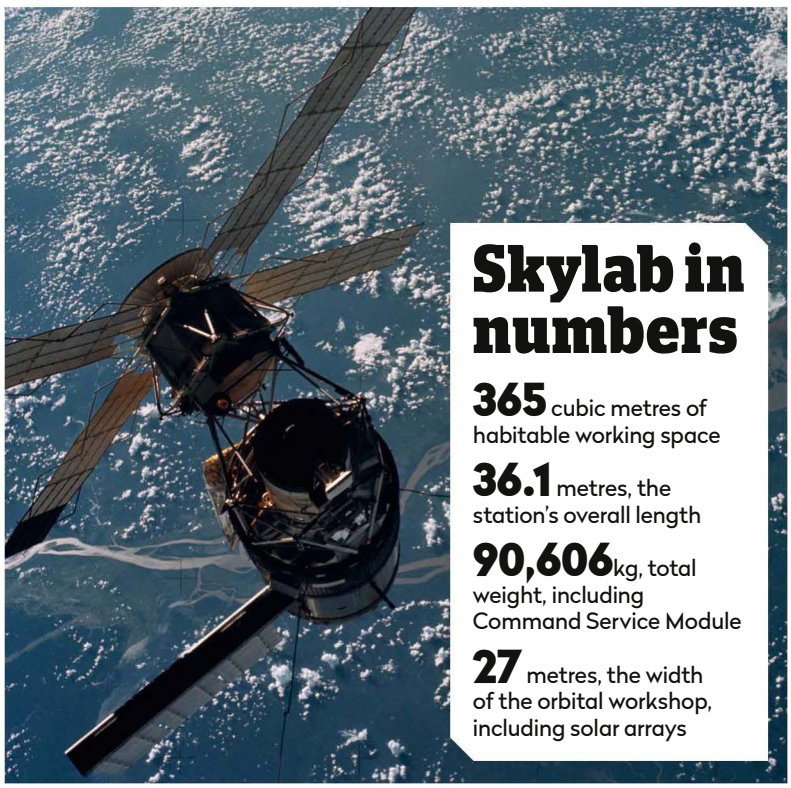
▲ 14 May 1973: the uncrewed Skylab is launched aboard a modified Saturn V rocket from NASA's Kennedy Space Center

▶ hydrogen, functioning as the rocket's second stage in ascent. Once in orbit, any residual fuel and oxidiser could be vented and the oxygen tank pressurised to give astronauts a breathable atmosphere. Pre-installed fittings could be made to the floors and walls – an aluminium grid structure with plentiful openings for fuel flow – enabling equipment to be mounted and experiments conducted. On top of the S-IVB stage could be a Multiple Docking Adaptor (MDA) with two docking ports – a prime axial one and back-up radial one – for the Apollo Command and Service Modules (CSM) ferrying crews and supplies. In the event of a spacecraft being disabled, a second two-person crewed Apollo CSM capsule could rescue resident crew, enabling all five astronauts to safely return to Earth.

But concerns arose about the time required for astronauts, working in zero-G, to unload copious equipment from the MDA and install it in this 'wet' workshop. By 1969, and with unused Apollo 18, 19 and 20 Saturn V rockets waiting in the wings, the decision was made to switch Skylab's launch from the smaller Saturn IB rocket to the much larger Saturn V. The greater capacity of the Saturn V meant that the S-IVB no longer needed to function as a rocket stage during launch. This 'dry' Orbital Workshop (OWS) could be outfitted on the ground, the hydrogen fuel tank serving as the main living quarters, with exercise equipment, a galley, zero-gravity shower system and the necessary instruments for scientific experiments. The liquid oxygen tank could be utilised as a waste facility.

Off to a shaky start

On 8 August 1969, after years of development and workshops, the McDonnell Douglas Corporation was awarded the contract to create an orbital workshop out of two existing S-IVB stages. The unpiloted Skylab (SL-1) – weighing 77,088kg and the only space station built and operated solely by the USA – was launched on a two-stage Saturn V rocket (SA-513) on 14 May 1973 from Kennedy Space Center's Pad 39A. Shortly after lift-off, a large micrometeoroid shield – installed to deflect debris and act as a thermal blanket – structurally failed. Within seconds, aerodynamic forces ripped it from the station. One of the two main solar array wings, designed to deploy in space, also partially deployed. Several minutes later, after the rocket's second stage burn, retro rockets fired, separating the booster from the station. Their exhaust hit the partially deployed solar array and tore it off. Later, in orbit, it was discovered that the other solar array had been tangled in debris and failed to deploy. With the micrometeoroid shield missing, the station was exposed to extreme levels of solar radiation – a withering 52°C (126°F). ▶



Skylab in numbers

365 cubic metres of habitable working space

36.1 metres, the station's overall length

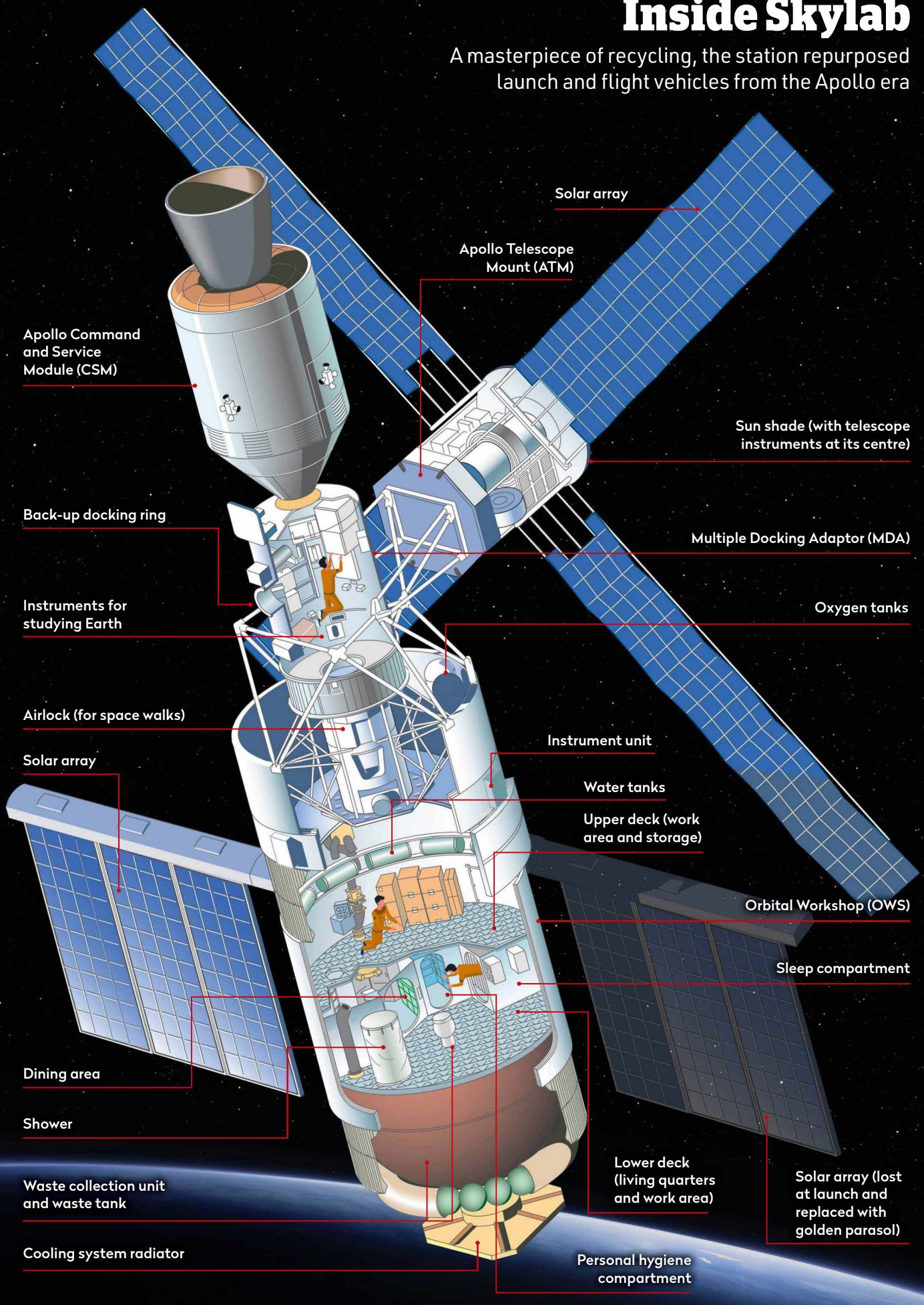
90,606kg, total weight, including Command Service Module

27 metres, the width of the orbital workshop, including solar arrays

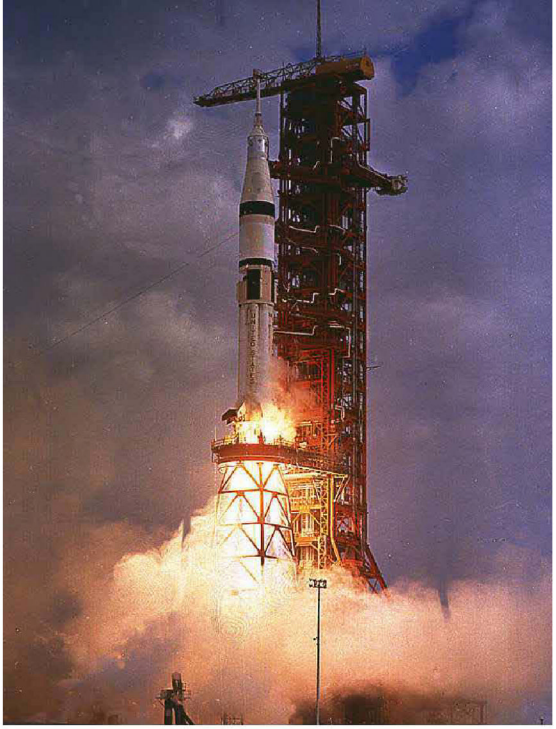
NASA X 3, ENCYCLOPAEDIA BRITANNICA/GETTY IMAGES, DIMA_ZEL/ISTOCK/GETTY IMAGES

Inside Skylab

A masterpiece of recycling, the station repurposed launch and flight vehicles from the Apollo era



The 'parasol' undergoes testing in May 1973. The emergency shade was rigged up by the first crew after a shield was ripped off at launch



▲ The first crewed mission to Skylab blasts off aboard a Saturn IB rocket on 25 May 1973. On board were astronauts Pete Conrad, Joseph Kerwin and Paul Weitz

▶ Mercifully, four solar arrays on the Apollo Telescope Mount (ATM) deployed as planned, giving sufficient power for Marshall Space Flight Center controllers to stabilise the station until repairs could be made. On 25 May, after a delay for tools to be modified and techniques developed, and after subsequent crew training, Skylab 2 (SL-2) launched on a Saturn IB rocket (SA-206) carrying the first Skylab crew: commander Charles 'Pete' Conrad, pilot Paul Weitz and science pilot Joseph Kerwin. On their second day in orbit, in searing temperatures, they deployed a 6.7m x 7.3m 'parasol' – a solar shade – through an airlock in the side of the OWS. Made of woven nylon, mylar and aluminium it instantly reflected sunlight and made the inside temperature bearable.

Speeding through the science

Along with the Orbital Workshop (OWS) and Multiple Docking Adaptor (MDA), there was the Airlock Module (AM), which could be sealed off and depressurised, enabling astronauts to exit via a large hatch to conduct spacewalks for changing camera film, performing experiments and doing routine maintenance. On 7 June, the crew used this facility to release the jammed solar array and deploy it fully, increasing the available power.

Also key was the octagonal Apollo Telescope Mount (ATM) to which three control moment gyroscopes (CMGs) were attached, stabilising the entire station. The ATM housed the four solar arrays and a battery of solar instruments. Inside, a cylinder, divided into four quadrants and gimballed to enable exquisite pointing control, provided mounting points for X-ray and hydrogen-alpha telescopes, a spectroheliograph, spectrographs, a spectroheliometer, cameras and a white-light coronagraph. Working at a complex control console, astronauts viewed and studied our nearest star in X-ray, extreme ultraviolet, ultraviolet and hydrogen-alpha wavelengths – an operation, according to commander Charles Conrad, akin to "playing three 88-keyboard pianos at the same time". Solar flares, filaments, coronal holes, coronal mass ejections and even a comet – Kohoutek – were observed and imaged with hitherto unrivalled clarity. These lengthy solar observations across the electromagnetic spectrum, above Earth's atmosphere, vastly increased our knowledge of the Sun and the heavens.

During its operational lifetime, Skylab orbited Earth more than 2,476 times. It was visited by a further two crews: Skylab 3 (SL-3) with commander Alan Bean, pilot Jack Lousma and science pilot Owen Garriott,

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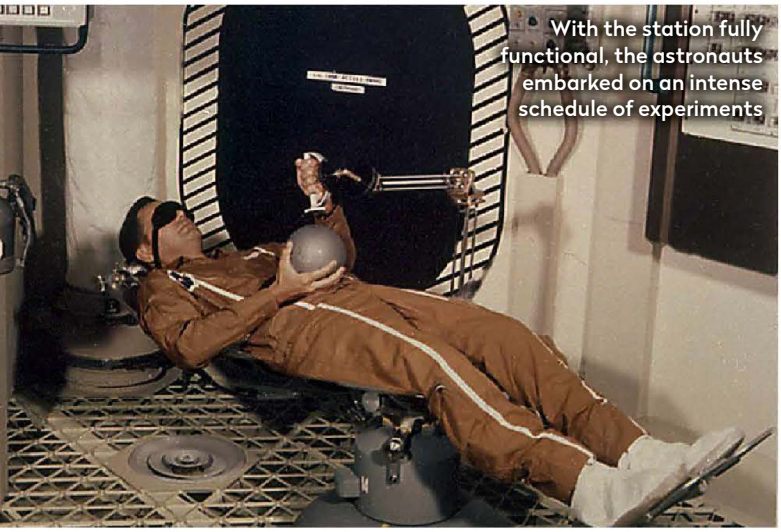


With the station fully functional, the astronauts embarked on an intense schedule of experiments

▼ Commander Pete Conrad takes a zero-G shower in the luxurious new station's living quarters

Skylab's dramatic ending

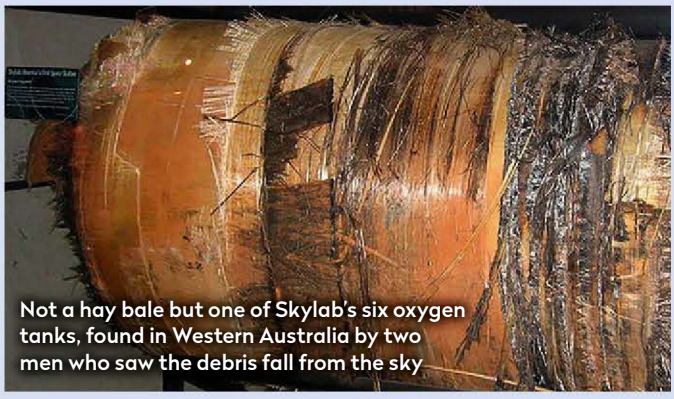
How do you deorbit a 77,088kg laboratory? That's the problem NASA faced in the summer of '79

Skylab's demise was a global media event. With NASA budget pressures leaving the redundant station lacking the control and navigation mechanisms to return it safely to Earth, the world celebrated but also feared its end.

On 6 March 1978, NASA ground controllers made contact with the empty station and on 24 April sent reactivation commands to reorient it, extending its lifetime and giving a predicted uncontrolled reentry of mid-1979. Having placed it in a high-drag solar-inertial attitude in January 1979, on 20 June it was manoeuvred into 'torque equilibrium', giving NASA the option of delaying or advancing its precise orbit for reentry.

At 07:45 UTC on 11 July, a tumble command was sent to Skylab from the Madrid tracking station in Spain, shifting the point of reentry away from Canada and the US eastern seaboard. Reentry occurred that day, during orbit 34,981, at approximately 16:37 UTC, the debris dispersion area stretching from the southeastern Indian Ocean and across a sparsely populated region of southwestern Australia.

Residents there spotted dozens of colourful flares as large chunks disintegrated 16km up in the atmosphere. Several US and Australian museums now house retrieved Skylab wreckage, including two chunks of oxygen tank, the smaller one dug up by an Australian rancher as recently as 1990.



Not a hay bale but one of Skylab's six oxygen tanks, found in Western Australia by two men who saw the debris fall from the sky

▲ The astronauts also conducted spacewalks, now a routine activity for crew on the ISS

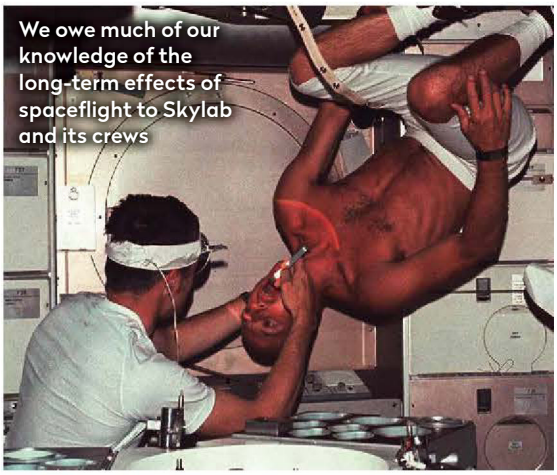
and Skylab 4 (SL-4) with commander Gerald Carr, pilot William Pogue and science pilot Edward Gibson. All were transported to the station by Apollo spacecraft launched on Saturn IB rockets. The Skylab 2 crew stayed 28 days (the longest continuous in-space stint at the time), with SL-3 and SL-4 crews staying 59 and 84 days respectively.

The crews achieved all of NASA's major goals. In addition to making stunning solar observations, they studied the physiological effects of prolonged periods of weightlessness. They observed Earth's crops and weather, and monitored environmental changes. They also carried out experiments in manufacturing alloys and growing perfect crystals in microgravity.

Skylab runs out of road

Skylab was expected to remain in orbit until at least November 1979 and at best March 1983, but unexpected increased solar activity – which heated Earth's upper atmosphere and increased drag – decayed its orbit. A fourth 20-day Skylab 5 crewed mission was considered; the Skylab rescue mission standby launch vehicle could boost the station to a higher altitude and the crew could conduct experiments. NASA even placed a contract to use a Teleoperator Retrieval System (TRS), launched aboard NASA's Space Shuttle, to robotically reboost Skylab's orbit (see Skylab's dramatic ending, above). Even destruction by missiles was considered. But in December 1978, with budget pressures and Space Shuttle missions stymied by delays, Skylab operations were shut down and it was parked in a 433km x 455km orbit. It fell to Earth on 11 July 1979.

Hailed by Rocco Petrone, director of launch operations at the Kennedy Space Center, as a "bold concept which opened new pathways in the sky", Skylab was NASA's most ambitious human spaceflight programme. Crucially, it proved that astronauts could live, work and overcome problems in an almost business-like manner in low-Earth orbit for extended periods of time. This achievement paved the way for permanent operations; NASA and ESA next focused on the reusable Spacelab module, an orbital workshop that could be deployed with the Space Shuttle. Along with the researched-but-never-built Space Station Freedom, this led to the construction of the International Space Station. But it all began with Skylab.



We owe much of our knowledge of the long-term effects of spaceflight to Skylab and its crews

Jane Green is an astronomy presenter, speaker, writer and fellow of the Royal Astronomical Society

The fundamentals of astronomy for beginners

EXPLAINER

How we know that Earth isn't flat

Astronomers have known that Earth is a globe for thousands of years

An astronaut's eye view makes it obvious, but we knew about Earth's curvature long before spaceflight

It's a common line to hear: "Five hundred years ago, they thought that Earth was flat!" But it's also completely untrue. Astronomers have been able to prove our planet is a globe for well over 2,000 years, using methods you can recreate at home.

The first known reference to a round Earth is in ancient Indian religious texts. The Rigveda, first composed between 1500 and 1000 BCE, includes the verse "In the midst of the Universe, the spherical Earth stays". Unfortunately, though there is much evidence of ancient India's extremely advanced knowledge of astronomy, there is little surviving record of their methods.

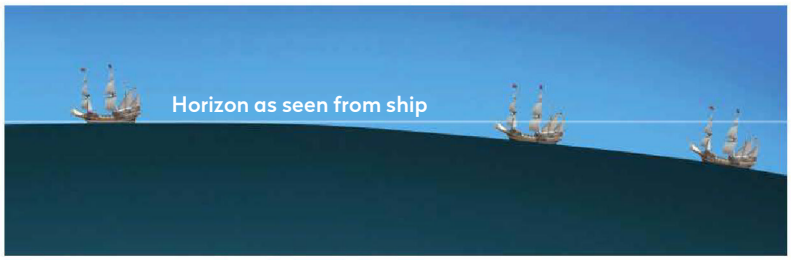
For that, we must turn to the Greek 'natural philosophers'. The first written evidence that Earth was a globe comes from Empedocles and Anaxagoras in around 430 BCE, both of whom noticed Earth's shadow appeared rounded during a lunar eclipse. You can look out for its curve yourself on 28 October, when the next lunar eclipse that's visible in the UK is due.

In 350 BCE, Aristotle added even more evidence. He noted that when a ship sailed beyond the horizon, the masts would remain visible after the hull had disappeared, as you would expect if it had sailed around a curved edge. If you're near a port you can do the same with modern ships, though you'll need to look for their upper decks, rather than sails.

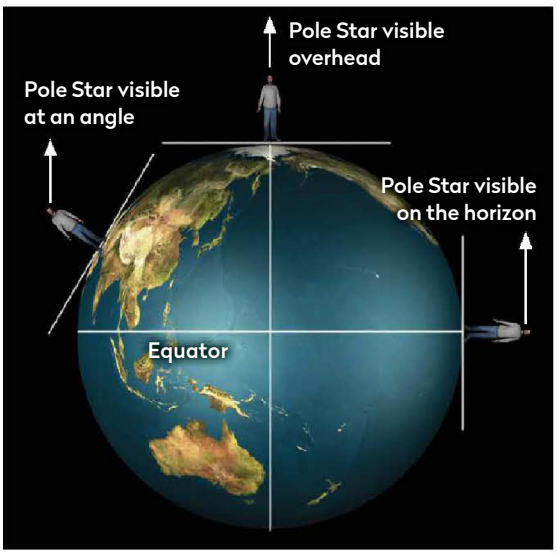
At the time, it was well known that different constellations appeared in different places – for example, the North Star is closer to the horizon in Cairo than it is in Athens. However, Aristotle was the first to suggest that because Egypt is further south, it would be looking at the star from a shallower angle if the world was a globe. Next time you take a holiday within the Northern Hemisphere, keep an eye out for the North Star and see how its position compares to back home.

Sizing up the sphere

The Greeks also noted the same effect caused the lengths of shadows to differ, depending on how far north or south you were. Several scientists used this



▲ Way back in 350 BCE, Aristotle saw evidence for the curve in the disappearing hulls of ships as they sailed away

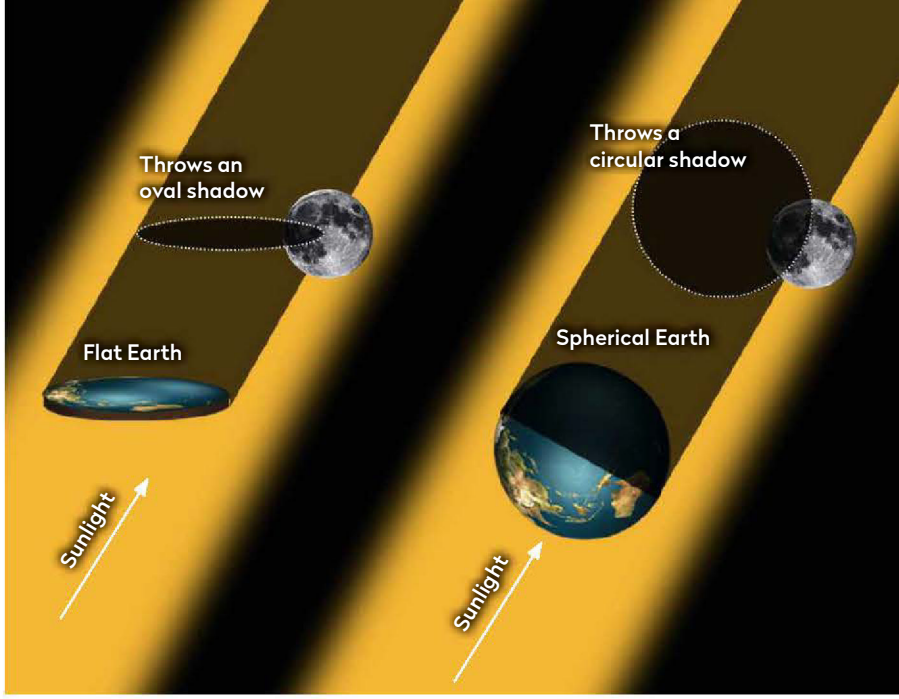


▶ To northern observers the Pole Star is higher in the sky – more proof of Earth's non-flatness

NASA, ILLUSTRATIONS BY PAUL WOOTTON, ROYAL ASTRONOMICAL SOCIETY/ SCIENCE PHOTO LIBRARY; SHEILA TERRY/SCIENCE PHOTO LIBRARY

to measure the circumference of Earth, but the earliest recorded account is from around 240 BCE. Eratosthenes, from the town of Cyrene (Aswan in modern-day Libya) knew there was a well in Cyrene where, at noon on a certain day of the year, the Sun would perfectly illuminate the water but not the well walls, showing the Sun was directly overhead.

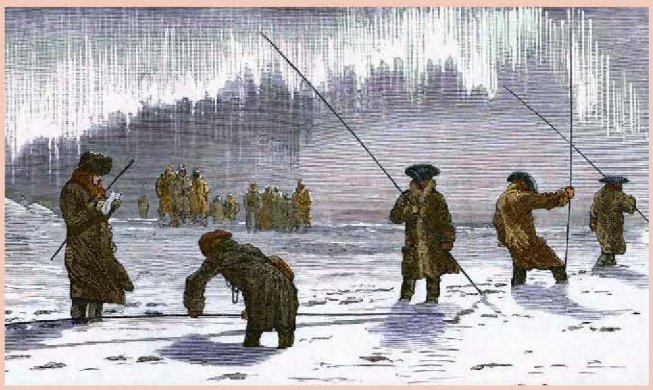
Later, he worked at the Library of Alexandria in Egypt, located hundreds of kilometres to the north. On the same day of the year, he erected a pole and used the length of the shadow to measure the angle of the Sun as 7.2°, around 1/50th of a complete circle. This meant the distance between the two cities was 1/50th of Earth's circumference. Fortunately, the distance had already been well measured, so he knew they were 5,000 stadia apart. The exact length of a stadia varied in the ancient world, but this puts Erastothenes's measurement between 38,000 and 46,000km – not far from the current measured circumference around the poles of 40,008km.



▲ **During an eclipse, Earth casts a circular shadow on the Moon, not an oval – something astronomers in the 5th century BCE knew suggested a spherical world**

Ezzy Pearson is *BBC Sky at Night Magazine*'s features editor. Her book *Robots in Space* is available now

Over the following centuries, knowledge of a globe-shaped Earth spread through the astronomers of Europe, India and the Arab world. However, the first direct proof that Earth was a spherical globe was in 1519, when the Magellan–Elanco expedition first circumnavigated the globe – though unless you are both extremely wealthy and an expert sailor, you might have trouble replicating that one at home.



▲ **Expeditions to the equator (above left) and to Lapland (right) proved that Newton was spot-on with his 1687 theory that Earth is slightly flatter towards the poles**

The shape of Earth

While it's clear our planet is spherical, its exact shape was harder to determine

The ancient Greeks believed that circles and spheres were the perfect shapes, a belief which carried over into Old World science. It wasn't challenged until the Enlightenment era, leading to two new theories about our planet's shape. French philosopher René Descartes's theories about vortices in the ether suggested Earth was shaped like an upright egg, stretched towards the poles. Meanwhile, Isaac Newton's theory of gravity suggested Earth's spin would make the equator bulge out, while flattening the poles.

Knowing which was true would greatly increase the precision of naval navigation, so the French and Spanish governments sponsored two expeditions to solve the issue. One would head to Lapland near the Arctic circle, the other to the equator, to measure the length of one degree of latitude. If Lapland was longer, Decartes was correct; if it was the equator, then it was Newton.

In 1735, an expedition set sail for the Andes in modern-day Equador. Bad planning, extreme weather, volcanic eruptions and a leader who spent much of the team's money buying diamonds for his mistress meant it was a decade before any crew member came home. By then, the Lapland expedition had long since returned, compared their own measurements to those taken in Paris, and proved that Newton's idea was correct.

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

Build an artificial star

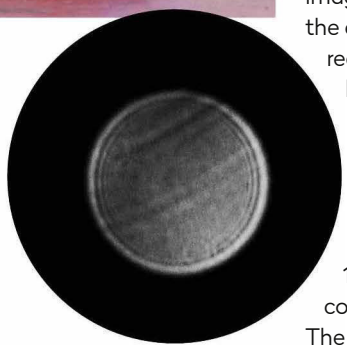
Make a useful tool to test the alignment and quality of any telescope or lens

Mark Parrish is a bespoke designer based in West Sussex

The 'star' is made from a lunch box with one hole for an LED torch and another to look through with your equipment

This month's project is an artificial star – a bright, pinpoint source of light, resembling a real star in the night sky – that can be used to test the alignment and quality of your telescopes and camera lenses. Real stars work perfectly for this sort of testing, but with an artificial star you can test your equipment whenever you like, including the daytime, saving the best nights for observing!

Our 'star' is produced by shining an LED torch through aluminium foil with a tiny pinhole in it. The illuminated pinhole is reflected in a shiny ball bearing, which improves the star effect and means that the artificial star and telescope don't need to be perfectly aligned. All the components are protected inside a robust box lined with black felt to absorb any stray light. In use, the box is placed at a suitable distance from the telescope. Some experimentation with the pinhole's size is recommended; smaller holes work best, but larger holes are brighter.



▲ Airy discs produced by a defocused 4-inch refractor using our artificial star

See the light

When the artificial star is viewed through a well-focused telescope, the image should be bright and sharp. If the optical elements are misaligned or low-quality, the star may not be circular or focused. If you slightly defocus the image, a series of normally concentric diffraction rings (called Airy discs) appear. These rings provide an enhanced indication of any problems with your setup. You can usually adjust (collimate) your telescope to correct a misalignment, making the rings concentric. There are also ways to mitigate against some of the problems seen with cheaper optics. For a useful introduction to collimating and star testing, visit **www.skyatnightmagazine.com/advice/how-to-star-test-a-telescope**.

If the elements of a camera lens are not of the highest quality or design, some colours of light may not focus together on the same point, causing blurry purple fringes around stars. By taking a series of images of a well-focused artificial star and varying the exposure settings (increasing aperture and reducing speed by one stop each time), you should be able to gauge which is the lens's widest useable aperture for astrophotography.

To properly star test your telescope with the artificial star, place it a minimum of 25 times the focal length of your telescope away. For a 200mm f/10 telescope that would be 200 x 10 x 25 = 50 metres away, but if you just want to collimate it you can place the 'star' much closer. The limiting factor is then how close an object can be while you can maintain focus on it.

MORE **ONLINE**

Download a diagram and more photos to help with your build. See page 5 for details

What you'll need

- Hand drill and bits – one suitable for the tube diameter and one approximately 12mm for the aperture
- Coping saw, scissors, craft knife, pencil, hot glue gun, pin
- Sturdy plastic lunch box, small LED torch with a switch on the end, PVC or cardboard tube just wide enough to fit the torch
- Offcuts of card or board for aperture and packing
- Black felt, aluminium foil, matt black spray paint
- Shiny ball bearing (8mm or so), short dowel

ALL PICTURES: MARK PARRISH

Step by step

Step 1

After marking the positions, drill holes in the lunch box to fit your torch tube and viewing tube. If you haven't got a large enough drill, you can enlarge a smaller hole with a craft knife, but take great care not to slip.

Step 2

Adapt our downloadable diagram to suit your box's size. Saw the three tubes to length and carefully remove any rough edges by scraping with a craft knife. You may need to cut some packing to put under the tubes to keep them level.

Step 3

Select the tube into which the torch will go. From a piece of board make an aperture disc to be glued to the end of the torch tube. It is easier to drill the 12mm hole before doing the cutting out. Use a glue gun to stick the aperture disc to the tube.

Step 4

All of the parts, including any packing, should be painted matt black inside and out to absorb any stray light that might otherwise reach the telescope. We painted the inside of the box and lined it and the viewing tube with some black felt.

Step 5

Cut a small piece of aluminium foil. Use a sharp pin to make a small round hole. You might need a few attempts to get a good example. You can experiment later with different-sized holes to see which gives the best results.

Step 6

Assemble using hot glue. Glue the ball bearing on a black dowel. Glue the dowel so that it appears centrally in the viewing tube and is also illuminated by the torch. Use tape to fix the foil over the torch aperture. Add light-absorbing felt as necessary.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Mars and the Beehive

Before twilight takes it, catch the Red Planet's last hurrah close to this stunning cluster

▲ **Mars passing across the Beehive Cluster in October 2011, imaged through Pete's f/3.3 reflector**

Mars is an iconic object in the night sky. Its brightness waxes and wanes over a 2.1-year period, appearing at its most brilliant around opposition. That was on 8 December 2022 and it now shows only a hint of its former glory. Its colour is a different matter, the planet retaining the beautiful orange-pink hue that makes it stand out so well.

Mars starts May at mag. +1.3, dimming only slightly by month end to mag. +1.6, still an easy naked-eye object. At that point it starts to battle with the evening twilight, but before it becomes totally engulfed it has one last show up its sleeve.

At the end of May it will be just west of the beautiful binocular open cluster M44, the Beehive Cluster. This is located in the heart of the winter/spring constellation of Cancer, the Crab. As we head towards June, Cancer isn't well-placed and the Beehive becomes engulfed by twilight.

Before it goes, starting in late May, try to find Mars low above the west-northwest horizon after sunset. If you can follow it as the sky darkens, you shouldn't have too much trouble locating the stars of the Beehive further to the east. A good flat horizon is highly recommended.

ALL PICTURES: PETE LAWRENCE

Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

Following our guide (opposite), see whether you can grab a shot of the planet and cluster together. Catch them early on, say from 22 May, to give yourself plenty of time to get acquainted with the settings needed. As May draws to a conclusion, the twilight becomes really tricky to deal with. This is a pity because in early June Mars passes directly across the face of the cluster. Obviously, this is a line-of-sight effect, the cluster being 20 million times more distant than local Mars, but it's definitely one that's worth pursuing if you have clear skies and flat horizons.

The dates to note are 1–3 June, the planet appearing inside the main part of the cluster on the evening of 2 June. The twilight conditions pose interesting challenges for astrophotography as the light levels are constantly changing. As the sky becomes darker, so the altitude of Mars and M44 drop. This moves them into a region of sky compromised by a thicker, often hazier atmospheric layer. This in turn will dim Mars and the cluster's stars.

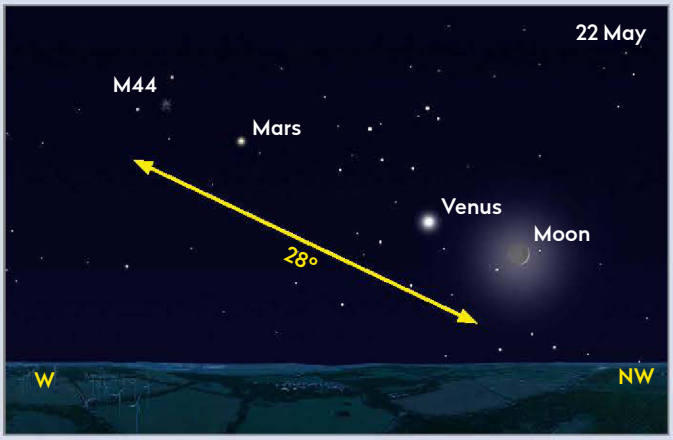
The whole scene is something of a balancing act. Try to capture it too soon and the sky brightness will ruin the shot. Wait too long and the low-altitude hazy atmosphere will dim everything, making it hard to grab a good image.

A mid- to long-focal-length lens will work well for the approach shots, while a long-focal-length lens or telescope is ideal for the evening of 2 June and Mars's transit of the cluster. A tracking mount is recommended as it will make the pair a lot easier to follow. However, with a brighter twilight sky, exposures need to be kept relatively short, meaning fixed, non-tracking mounts should work fine too. If using a DSLR on a fixed platform you may need to up the ISO so exposures are short enough to avoid trailing.

Equipment: DSLR camera with lens or telescope, tripod or preferably a tracking mount

✉ Send your images to:
gallery@skyatnightmagazine.com

Step by step

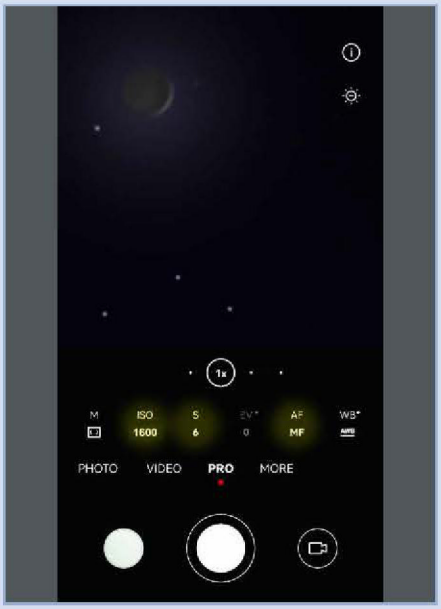


STEP 1

There are some lovely chances to capture the Beehive, Mars, Venus and the waxing crescent Moon from 22 May onwards. Around midnight BST on 22 May, the widest Moon–M44 separation is 28°. Choose a lens that covers say 35–40°; 50mm for full-frame cameras or 30mm focal length for APS-C should work well.

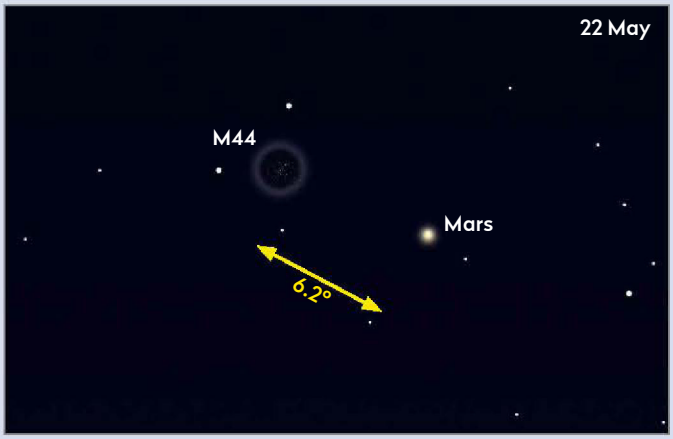
STEP 2

If you have a smartphone, why not give that a go as well? It's recommended to mount the phone with an inexpensive tripod adaptor for stability. Experiment with the basic mode first. If that doesn't work, try a night shoot mode if your camera has one. Alternatively, if it has a pro mode that allows you to adjust settings, try that.



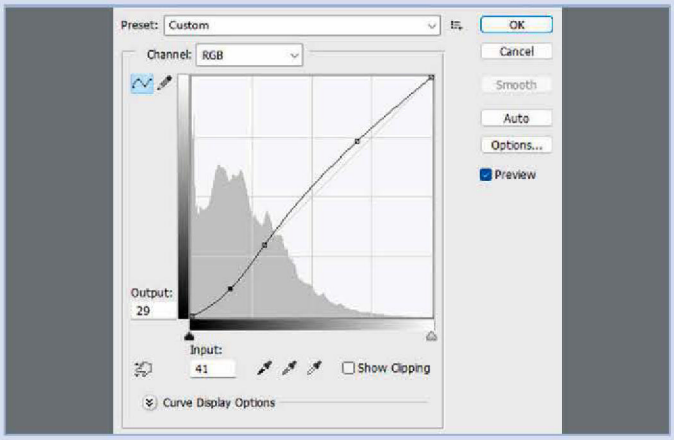
STEP 3

For a basic shot with a phone camera, set the focus to manual (MF) and ISO to 400–1600 and experiment with the exposure settings. The Moon and Venus should record easily and Mars shouldn't pose too much of an issue either. The cluster stars may be trickier, depending on the capabilities of your phone's camera under low-light conditions.



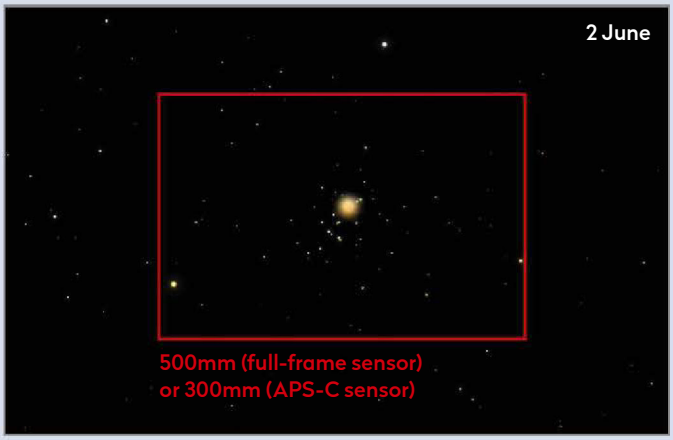
STEP 4

From 22 May, Mars will be moving closer to the cluster. On that date it lies 6.2° to the west of M44, nicely framed by a 240mm lens (full-frame) or a 150mm lens (APS-C). With a twilight-bright sky, choose a low ISO and a lowish f-number, and adjust the exposure to give a well-saturated but not over-exposed image.



STEP 5

Careful tweaking can improve the visibility of the cluster stars. A gentle 'S' shape on the Curves adjustment tool and subtle changes to brightness and contrast will bring out their best. Consider using sharpening too, but be careful not to overdo this as it can create edge fringes that detract from the final result.



STEP 6

As we head into June, the separation will decrease, Mars appearing in front of the cluster on 2 June. By this date, twilight will be an issue. A longer focal length will help you zoom into the cluster and darken the sky slightly. A 500mm lens (full-frame) or 300mm lens (APS-C) will get you right into the action.

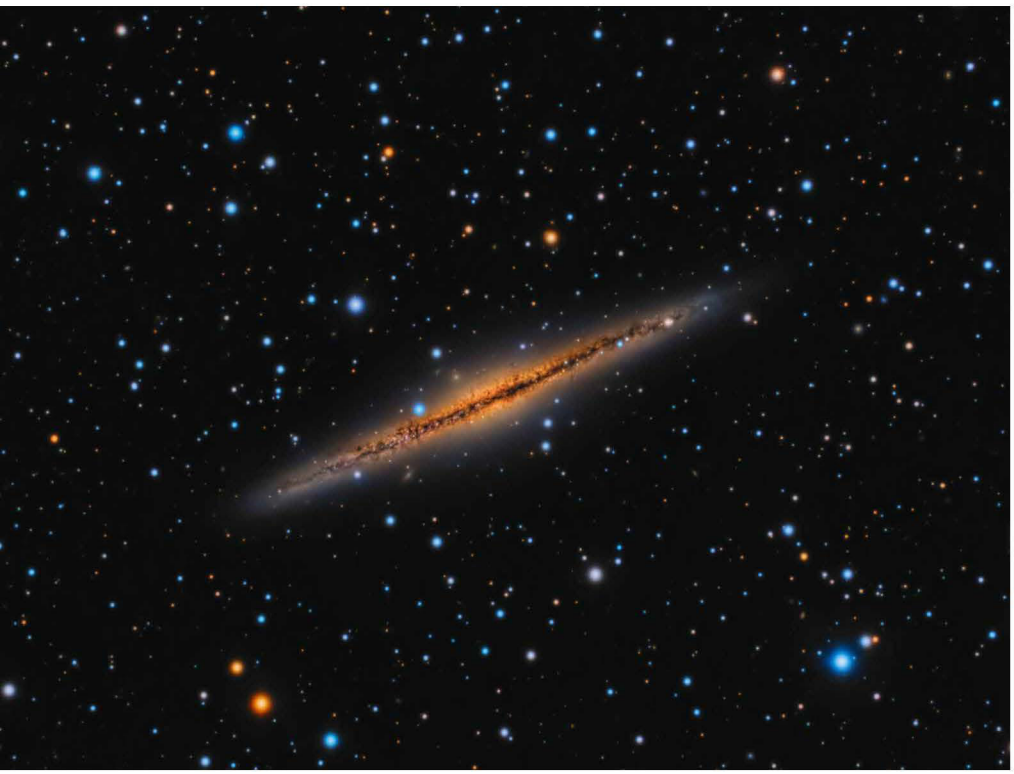
Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

How to accentuate the beauty of edge-on galaxies

Tips to enhance dust lanes in your astrophotos

Astronomy Photographer of the Year
Advice from a 2022 shortlisted entrant in the 'Galaxies' category



▲ **'Edge-On', Jason's original shortlisted image of galaxy NGC 891, 30 million lightyears away in the Andromeda constellation, which he revisits and reprocesses here**

ALL PICTURES: JASON GUENZEL

A backyard astrophotographer will often strive for world-class results. Perhaps it is in our nature. But rising to this challenge requires continued improvement in post-processing techniques and also careful consideration of attainable goals for each project.

In years past, I was honoured to be recognised and awarded in the annual APY exhibition. It happened again in 2022 as my image, 'Edge-On', was shortlisted in the 'Galaxies' category. It's interesting to revisit it and consider what makes this particular image stand out above thousands of other submissions.

The target is NGC 891, a beautiful spiral galaxy 30 million lightyears distant. Our vantage point lies along the plane of its galactic disc. We are treated with a spectacular edge-on view: a diffuse stellar halo crossed with a complex, backlit dark dust lane. The contrast within these delicate and wispy features creates a visual drama that draws the eye deeper into the galaxy. Highlighting this dust was a definite goal from the beginning.

If we consider each workflow to be a unique creative journey, that artistic vision of the end product can serve as a guide to our processing choices. The aim is to simply serve the image, assessing what is needed and continually adjusting course as necessary. A capable collection of tools can be used to steer, with subtle corrections, towards that ultimate goal. Here is a brief overview of some post-processing concepts for dust lane enhancement, widely applicable to galactic images.

Back to the raw

I started with the raw stack for the monochrome luminance filter, as this channel conveys visual details in the image (see Step 1). Deconvolution in PixInsight mathematically sharpens the image based on data contained within. When I originally processed 'Edge-On', I used an elaborate workflow of mask generation and deconvolution. Ultimately this can be replaced by the new BlurXTerminator plug-in from RC-Astro (**www.rc-astro.com**). In reprocessing this photo, I can confirm the results to be directly comparable to my previous process, and with just a single button click!

Noise Reduction in PixInsight reduces the noise without destroying fine detail. For this demonstration, another RC-Astro tool, NoiseXTerminator, does an excellent

▲ **Step 1: original raw image stack (top) captured with a ZWO ASI1600MM and Celestron 8-inch EdgeHD, 696x 90", 17.4h total; (middle) the image after RC-Astro's BlurXTerminator one-click plug-in was applied; and (bottom) after NoiseXTerminator was applied**

▲ **Step 2: The resulting image after stretching and applying RGB colour (left) and with high-pass filtering applied (right) at radius scales 3, 6, 12, 24 and 48 to enhance contrast before blending in 'Overlay' mode as layers in Photoshop**

▲ **Step 3: The final cropped and reprocessed image after using a combination of enhancement tools, plug-ins and scripts to bring out the beauty of the dust lanes**

job of protecting the details within the galaxy while effectively reducing background noise.

After stretching and applying colour to the previous result in Photoshop (see Step 2), I turned to contrast enhancements. Several software packages are capable, but Photoshop offers the benefit of working in layers of varying opacity while still providing real-time visual feedback. Creating projects consisting of many layers using different enhancement processes, and blending them into each other in creative ways, can yield results unobtainable with single processes executed in a serial fashion.

One effective method of multi-scale contrast enhancement is high-pass filtering. Start by duplicating the original layer. With the new layer selected, navigate to Filter › Other › High pass. The 'Radius' slider allows you to choose the scale of the effect (smaller radii will emphasise smaller structures). Click 'Ok' and then change the blending mode of the layer to 'Overlay' (or 'Soft light' for less effect). The layer opacity can be lowered to provide a subtle contrast enhancement. I repeated this technique multiple times at different radius scales and layer opacities. I used masks to limit the effect to exactly where it was needed in the galactic core (see Step 2).

Other interesting tools to try for local contrast enhancement include: Camera Raw filter (clarity/texture/dehaze), Shadows/Highlights adjustment tool in Photoshop, along with plug-ins from Topaz Labs. PixInsight has a DarkStructureEnhance script, LocalHistogramEqualization process and HDRMT process.

It's easy to overuse these tools. The finesse of a light touch is important. Work in small, targeted and progressive changes (baby steps!) so that the results are neither harsh or unnatural. Using low-opacity layers and effective masking, multiple techniques can be combined to gradually build the desired effect, as seen in the reprocessed result (see Step 3).

I hope this provides some insight into a useful thought process and workflow ideas. Keep an initial vision in mind. Work with purpose, but also a high degree of care, to let that natural beauty of the cosmos shine through.

3 QUICK TIPS

1. The goal is to simply serve the image; assess what is needed and continually adjust course as necessary.

2. Layers blended together in creative ways can yield results unobtainable using single-process methods.

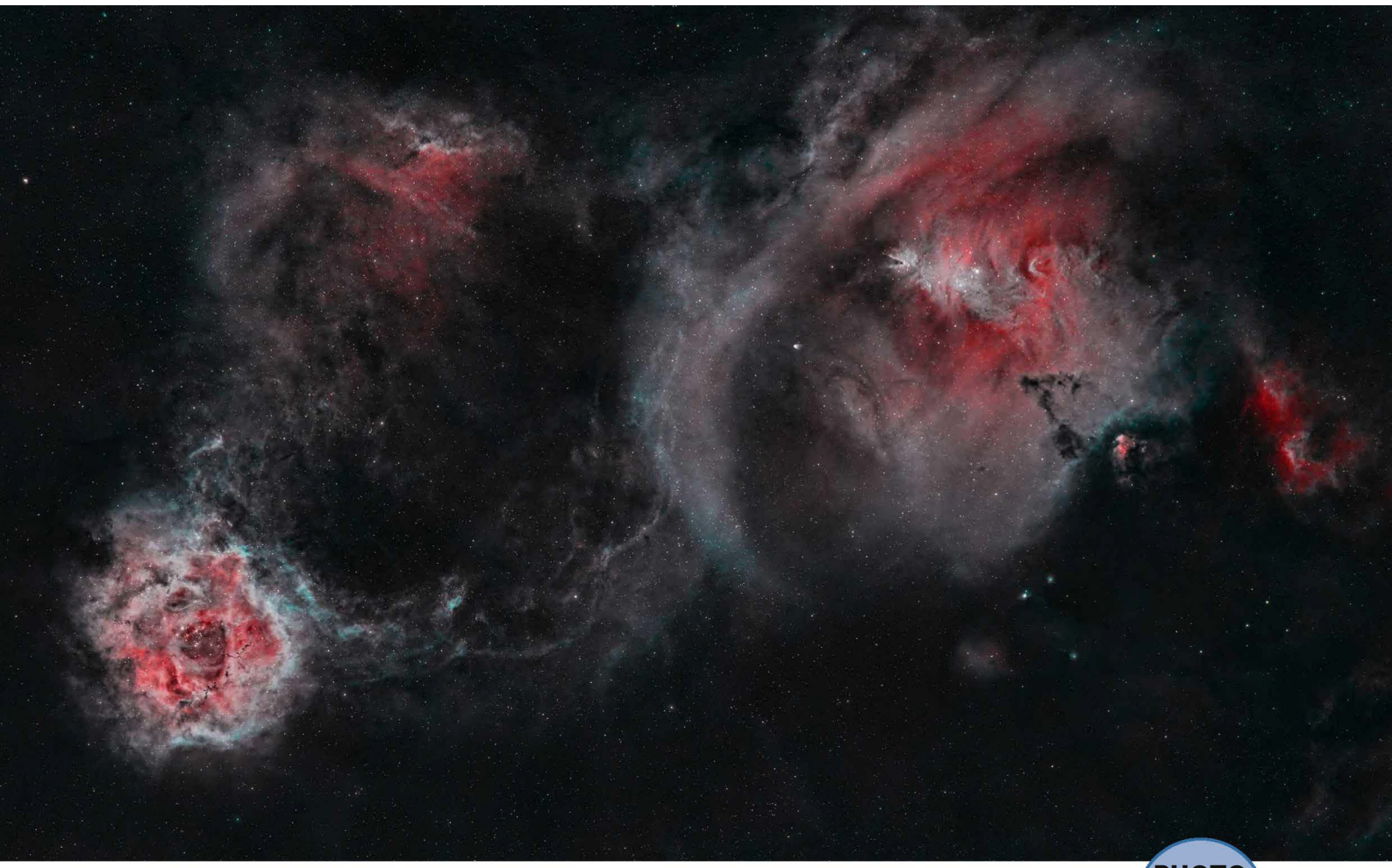
3. It's easy to overuse these tools. Have a light touch!

Jason Guenzel is an avid amateur backyard astrophotographer aiming to share the natural beauty of the night sky

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images



△ The Rosette Nebula and the Cone Nebula

PHOTO OF THE MONTH

Tim Barry, Milton Keynes, Buckinghamshire, 6, 7, 13 and 26 February 2023

Tim says: "I've been looking for a good target to try out US astrophotographer Chad Leader's 'HoSS' palette for a while, and the area around the Rosette Nebula and the Cone Nebula has proved to be a good candidate. I like the moody, smoky look that it brings to the image, with the teal highlights in the sulphur areas. The image was shot over several nights from a Bortle 5 location just outside Milton Keynes."

Equipment: ZWO ASI2600MC Pro camera, Samyang 135mm lens, Sky-Watcher HEQ5 Pro mount
Exposure: SII and OIII 115x 5', Ha and OIII 55x 5'
Software: PixInsight, Photoshop

Tim's top tips: "Using Chad Leader's HoSS palette makes a nice change from processing in SHO and HOO. Using two dual-bandpass filters with a one-shot colour camera opens up lots of different palette choices in addition to the traditional SHO palette. I used an IDAS dual-band nebula-boosting filter (NBZ) for H-alpha and OIII, and an IDAS narrowband nebula filter (NB3) for SII and more OIII.

The HoSS palette uses a blend of H-alpha and OIII in the red channel, and SII data in both the green and blue channels. This can be achieved in PixInsight by using the PixelMath tool. The H-alpha data can also be used as a luminance layer using PixInsight's LRGB Combination tool."

The Monkey Head Nebula ▷

Sara Harvey, Cork, Ireland, 5 and 25 January, 22 February 2023

Sara says: "I just upgraded my telescope and this seemed like the perfect target to get first light. After trying a few different narrowband combinations, I settled on an OHS palette."

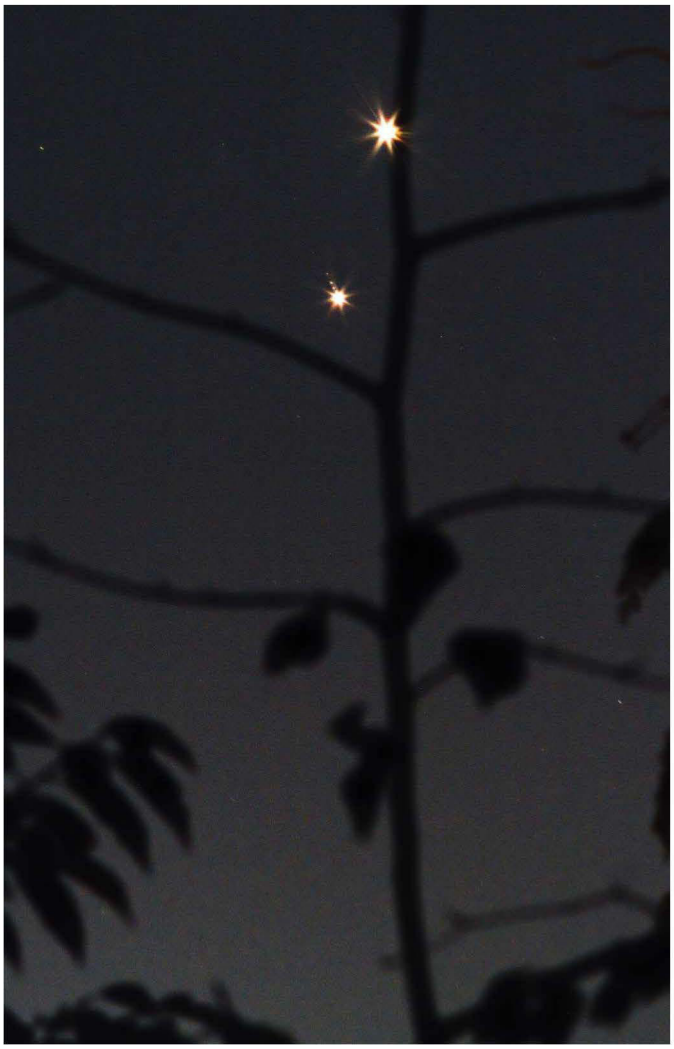
Equipment: ZWO ASI1600MM Pro camera, Takahashi FSQ-85ED refractor, Sky-Watcher HEQ5 Pro mount **Exposure:** OIII 35x 360", Ha 48x 360", SII 43x 360" **Software:** APP, PixInsight

▽ Venus and Jupiter

James Robertson, Croydon, 2 March 2023

James says: "I saw the planets in a lucky gap between trees and buildings, set up very quickly, and was very happy to capture Jupiter's moons with such a short exposure."

Equipment: Canon 750D DSLR, Olympus Zuiko 75–150mm lens, tripod **Exposure:** 3" **Software:** Photoshop



▽ NGC 1097

Massimo Di Fusco, remotely via Chilescope, Chile, 13–19 January 2023

Massimo says: "This barred spiral galaxy is very difficult to process due to the very bright nucleus. I managed to obtain a balanced result processing the nucleus and the whole galaxy in different ways and, at the end, combining it all."

Equipment: FLI PL16803 camera, ASA RC-1000 Ritchey–Chrétien, ASA altaz mount **Exposure:** Ha 7x 600", L 22x 600", RGB 7x 300" **Software:** APP, PixInsight, Photoshop

△ The Sombrero Galaxy

Dan Crowson, remotely via Telescope Live, El Sauce Observatory, Chile, August–September 2022

Dan says: "M104, the Sombrero Galaxy, 28 million lightyears away, is one of my favourite galaxies. It was one of the first that I attempted to image from my backyard near Saint Louis, Missouri in the US."

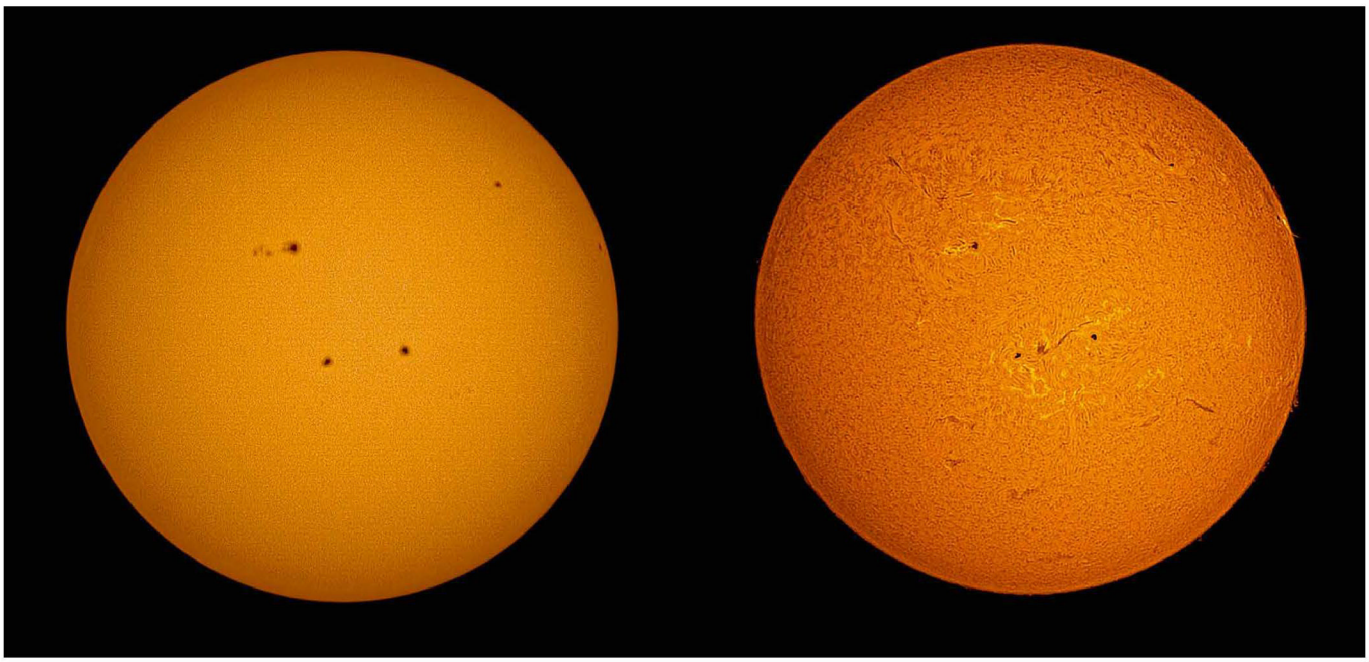
Equipment: QHYCCD QHY600M camera, PlaneWave CDK24 astrograph, Mathis MI-1000 mount **Exposure:** 7.8h total **Software:** PixInsight, Photoshop

▽ The Sun

David Hoskin, Halifax, Nova Scotia, Canada, 15 February 2023

David says: "A clear sky and temperature well above freezing was all the encouragement I needed to image the always fascinating photosphere and chromosphere of our nearest star."

Equipment: Player One Apollo-M Mini camera, Orion ST80A reflector (white light, left), Lunt 40mm solar scope (Ha, right), Baader solar filter, Sky-Watcher Star Adventurer mount **Exposure:** 0.062ms, 2ms, 4,000 frames per video **Software:** AutoStakkert!



The Moon, with a Boeing 737 ▷

John Tipping, Northwich, Cheshire, 11 June 2022

John says: "I was lucky to catch an aircraft passing by – it was a Ryanair Boeing 737 going from Malaga to Edinburgh."

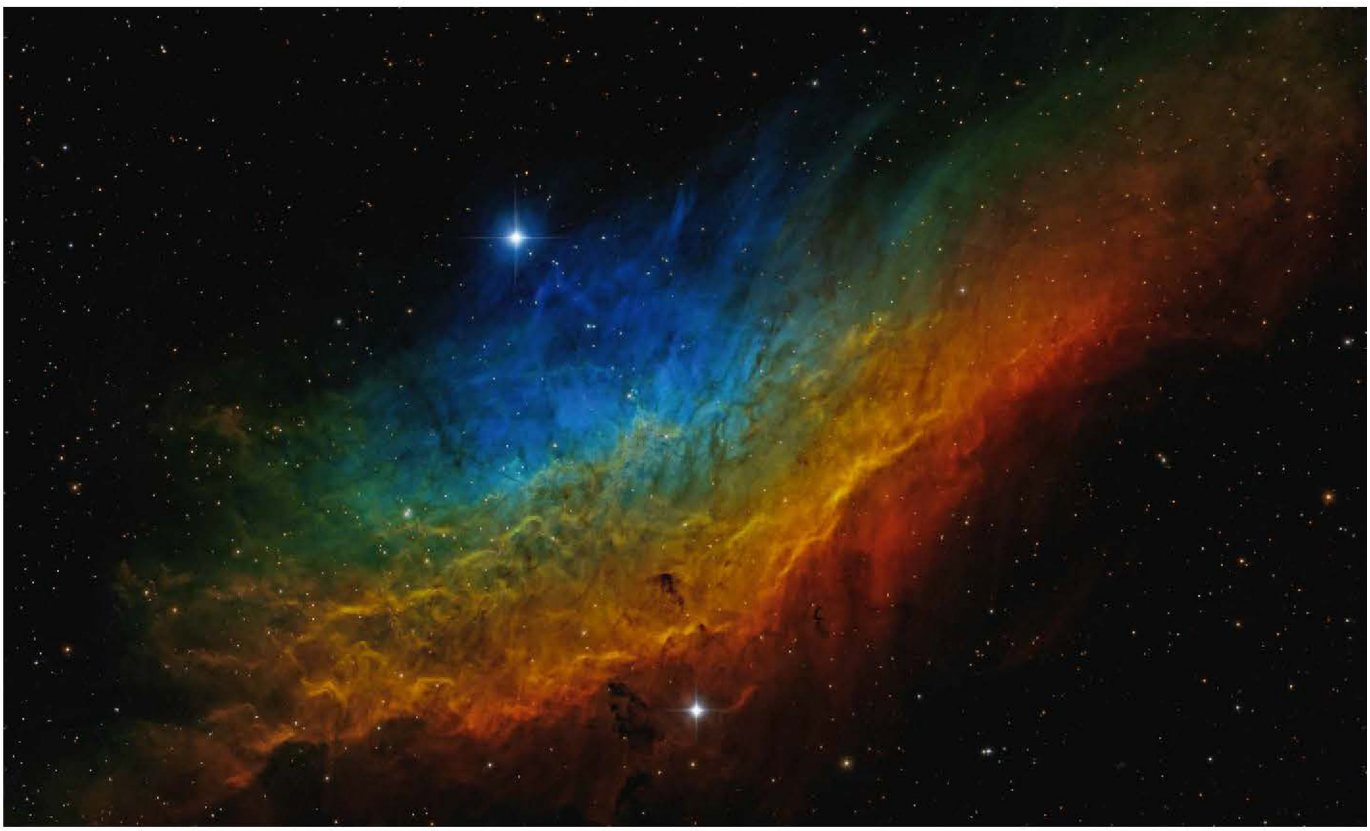
Equipment: Canon 700D DSLR, Sky-Watcher SkyMax 180 Pro Maksutov, iOptron iEQ45 Pro mount **Exposure:** 12,000 frames **Software:** RegiStax, FastStone Image Viewer

▽ The California Nebula

Neil Corke, Castilléjar, Spain, January–February 2023

Neil says: "I chose this nebula as I'd just upgraded to a full-frame camera and could fit it in the field of view with my Takahashi refractor. I used narrowband filters and processed it in the SHO Hubble palette, resulting in a colourful rainbow-like image."

Equipment: Moravian C3-61000 Pro camera, Takahashi FSQ-106 refractor, Software Bisque Paramount MX+ mount **Exposure:** 49h total **Software:** PixInsight, Photoshop



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The best in equipment, accessories and books each month

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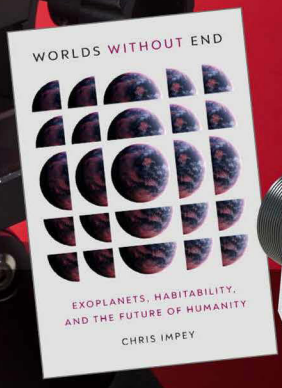
HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid



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FIRST LIGHT

Pegasus Astro NYX-101 harmonic gear mount

Well-built, high-precision mount that makes light work of really heavy lifting

WORDS: TIM JARDINE

VITAL STATS

- **Price** £3,490 (mount £3,095; tripod £395)
- **Mount type** harmonic drive dual mode (EQ/altaz)
- **Load capacity** 20kg; 30kg with counter-weights
- **Slew speed** up to 5° per second
- **Power input** 12v DC (PSU included)
- **Autoguider port** ST4
- **Protocols** ASCOM, INDI, Sky Safari (LX200)
- **Weight** 6.5kg mount; 2kg tripod
- **Supplier** Widescreen Centre
- **Tel** 01353 776199
- **www.** widescreen-centre.co.uk

With a name straight out of Greek mythology, where Nyx is the goddess of the night, the new NYX-101 is a harmonic drive mount from Greece-based Pegasus Astro. We received the NYX-101 mount and matching Pegasus carbon-fibre tripod as a package and right away we were really impressed by the lightweight nature of both items and the quality of materials used, along with the attention to detail in the machining of the various components, even down to the locking power lead connector and easy-to-adjust alignment handles.

Both the mount head and tripod come with a protective carry bag, making them highly portable, with a combined weight of just 8.5kg. A huge benefit of harmonic drive mounts is that they don't require any counterweight system unless you are using really heavy equipment, making them exceptionally travel-friendly. In fact, there is no need for a counterweight or bar at all with loads of up to 20kg.

As it happened, new firmware for the mount was released just after we received our review model. Pegasus Astro has a good reputation for ongoing improvement and support, and the upgrade was carried out by connecting the mount to our home Wi-Fi network. Initial setup of the mount requires linking it to a PC via USB 2.0, but afterwards it can be controlled wirelessly over its own Wi-Fi network, which has a reasonable range of a few metres. We found the most stable connection was via USB, as our mobile devices had a habit of losing connection to the Wi-Fi, sometimes mid-slew – a shame, because controlling the NYX-101 with Sky Safari was most enjoyable.

Taking control

Pegasus Astro provides the Unity control app for Android or iOS devices, and although it felt like a beta version, everything worked as it should. A feature of the app is that the directional control buttons are configured to move the mount to north or south and so on, but in practice this meant the direction of movement on a particular button might swap with consecutive presses, depending on mount position, which we found a little annoying. ▶

Dual-mode operation

The NYX-101 is easily configured in altaz or equatorial mode with a simple adjustment between the two options. Setting the appropriate configuration within the Unity app is as simple as one click too, offering a rapid choice between a traditional altaz viewing session or a full-on astrophotography outing.

ALL PHOTOS: @THESHED/PHOTOSTUDIO

Universal saddle

The NYX-101 has a universal saddle for attaching your telescope to the mount, accepting both Losmandy and Vixen-style dovetail bars. The dual locking nuts held our equipment firmly, but we did feel that slightly larger knurled handles would have been easier to tighten one-handed while holding a telescope in place.

Tripod

The dedicated Pegasus Astro carbon-fibre tripod weighs a mere 2kg, but will support 15kg of gear for imaging or a whopping 50kg in total. The tripod is well-built and the legs easily extend and lock. The anodised components are reassuringly well-made, while a bubble level is included for basic levelling.

Connectivity

Communication between the mount and a PC is via a USB 2.0 cable and Wi-Fi. The NYX-101 connects to your home Wi-Fi network, a step that is necessary for updating firmware, as well as producing its own Wi-Fi signal which allows for wireless control via a laptop, mobile phone or tablet.

Padded shell cases

Both mount and tripod are protected from damage and dust when travelling or in storage with a custom-made padded case. The cases are large enough to contain everything associated with the mount and tripod, and compact enough for easy transport. In fact, we could easily carry both items in one hand.

Harmonic drive system

Rather than traditional worm-drive gearing, the NYX-101 uses strain wave gears on both the RA and dec. axes. These mechanisms are typically used in manufacturing robots as they allow for very precise movements, high-torque loads and maintenance-free operation for many years. Compared to worm-drive gears that are prone to backlash issues, strain wave gears offer much higher reduction ratios within the same-size unit. For the NYX-101 this allows a high-precision 500:1 reduction on the all-important RA axis, giving a resolution of 0.10 arcseconds, while the less critical dec. axis works at 300:1.

In practice, the harmonic drive system delivers a lightweight mount with reliable and steady operation, particularly suitable for guided astrophotography. Once the mount is pointed at the polar axis and a suitable star alignment procedure has been carried out, the precision and accuracy of the Go-To commands was impressive. We found that even at 2,800mm focal length, the NYX-101 would reliably put the chosen object in the field of view of our 23mm eyepiece.

▲ One of a selection of 30-second exposures of comet C/2022 E3 ZTF captured during a 3-hour test of tracking performance. On board were a Canon 6D and Pentax 75mm SDHF refractor

◀ The NYX-101's calibration and guiding proved excellent over a tour of Messier objects like M42, the Orion Nebula. 10x 30" frames

KIT TO ADD

1. Pegasus Astro NYX-101 EQ6/universal adaptor

2. Pegasus Astro 3-piece aluminium standoffs

3. Pegasus Astro power cables

▶ At first we configured the mount for equatorial use with a short 75mm refractor. With a rough polar alignment and then a three-star alignment routine via the app, we were soon navigating to various objects. The Go-To function for this widefield view was very accurate. Before we tried something more challenging, we took the chance to try autoguiding. A multi-use ST4 port is included that can be used for guiding or for a hand controller, but we took advantage of the ASCOM connectivity in telescope-guiding software PHD2. The NYX-101 also offers INDI protocol and Sky Safari options with LX200 compatibility.

With a DSLR on the telescope and an off-axis guider, within a couple of minutes PHD2 was calibrated and guiding steadily, allowing us to take a few shots of January's green comet, C/2022 E3 ZTF, and the Orion Nebula. The mount easily handled guiding to these objects.

To really test the limits of the NYX-101, we brought out our Celestron 11-inch EdgeHD, a large telescope that with its accessories weighs over 15kg. It was not without some trepidation that we attempted the first slews with the scope in place. It seemed an unnaturally big load without any counterweights balancing it, but we need not have worried. The NYX-101 did not miss a beat, easily and accurately moving the mount between targets.

In altaz mode, with an accurate setup and alignment, the Go-To performance was excellent, allowing us an enjoyable mini Messier marathon as we quickly hopped to various objects in the Unity app catalogue. Ideal as a travelling mount and capable enough for permanent observatory installation, Pegasus Astro's NYX-101 offers a modern, accurate and competitively-priced mounting option both for observers and astrophotographers.

VERDICT

Assembly	★★★★☆
Build & design	★★★★☆
Ease of use	★★★★☆
Go-To accuracy	★★★★★
Stability	★★★★☆
OVERALL	★★★★☆

Sky-Watcher Evolux 82ED refractor

A dinky, smart, grab-and-go scope that still delivers big on performance

WORDS: CHRIS GRIMMER

VITAL STATS

- **Price** £649
- **Optics** air-spaced doublet refractor with ED lens
- **Aperture** 82mm
- **Focal length** 530mm, f/6.45
- **Focuser** CNC-machined dual-speed rack and pinion
- **Extras** tube ring, Vixen-style dovetail bar, 2x finderscope brackets, carry case, 2-inch eyepiece adaptor
- **Weight** 2.9kg
- **Supplier** Optical Vision Ltd
- **Email** info@opticalvision.co.uk
- **www.**opticalvision.co.uk

As the name suggests, the Sky-Watcher Evolux 82ED is an 82mm-aperture refractor that builds on the legacy left by Sky-Watcher's Evostar range, popular with beginner and intermediate astronomers. However, at 2.9kg and a mere 425mm long when the dew shield is retracted, the Evolux is designed as a more compact and lightweight addition to Sky-Watcher's lineup.

The Evolux 82ED arrived in a single box, revealing a solid and well-padded aluminium carry case. We were surprised at how compact this was for an OTA (optical tube assembly) of this aperture and focal length. We immediately appreciated the lightweight build and noted the extra-long dew shield, which gives extra protection from the elements when fully extended. A single clamshell-style tube ring with a pair of finder/guidescope brackets connects firmly to the short Vixen-style dovetail bar. At the back, Sky-Watcher has dropped the Crayford-style focusers seen on other models for a more robust 2.4-inch rack and pinion focuser. This utilises a linear geared bar on the underside of the focus barrel, which promises to hold a greater weight with less risk of slippage than legacy Crayford focusers which rely on friction alone to maintain position.

All features great and small

The Evolux's weight and dimensions render it a perfectly portable grab-and-go telescope, suitable for both astronomy and astrophotography. Cosmetically, the refractor is finished in the traditional white and green associated with modern Sky-Watcher products, which makes for an attractive setup. However, the impressive lightweight spec appears to have been achieved by using thinner materials. Although well put together, the OTA's construction feels perhaps less robust than older models. The dew shield also feels very thin, and while retracting and extending it we noticed a slight judder ▶

Bright, wide views

The Evolux 82ED is an air-spaced doublet apochromatic refractor that uses extra-low dispersion (ED) glass for one element, with a matching crown element. ED glass has been specifically formulated to reduce chromatic aberration when used in a twin-lens (doublet) configuration. The ED glass helps focus all three colour channels (red, green and blue), reducing the coloured halos often seen in single or double-lens refractors. The ED glass element also improves light transmission and, combined with Sky-Watcher's Metallic High-Transmission Coatings (MHTC), claims to offer 99.5 per cent light transmission.

At 530mm focal length (f/6.45) native or 477mm (f/5.8) with optional focal reducer, the ED82 offers a good range of focal lengths. The longer end, when paired with smaller-chip cameras, will work well for galaxies, smaller nebulae and globular clusters. Adding the optional focal reducer brings larger nebulae and galaxies into play, like Andromeda and Orion. With this range of options, you will not be short of targets in any season.

©THESHED/PHOTOSTUDIO X 3, STEVE RICHARDS

Dew shield

The extra-long fully retractable dew shield is secured in place by a pair of thumb screws, so there is no risk of it slipping even when pointing directly up. Due to the single-bracket tube ring, the dew shield can be fully retracted, making for a very compact telescope.

Clamshell tube ring

A single-bracket clamshell-style tube ring securely holds the Evolux 82ED in place. There are a pair of thumb screws to tighten the tube ring, allowing adjustments to be made quickly and easily even if wearing gloves. Attached to the top is a pair of finder/guidescope brackets.

Adjustable Vixen-style mount

Attached to the clamshell tube ring is a short Vixen-style dovetail bar secured by two Allen key bolts. The dovetail bar is 45mm long and is drilled in multiple places. This allows the attachment position to be fully adjusted, enabling balance to be achieved when eyepieces and cameras are attached.

Focuser

The Evolux 82ED is fitted with a 2.4-inch dual-speed rack and pinion focuser, which is an upgrade to the Crayford focuser on Sky-Watcher's Evostar models. The barrel of the focuser is etched with a measurement scale to enable quick and precise focusing time after time.

FIRST LIGHT

KIT TO ADD

1. 0.9x ED focal reducer/ flattener

2. M48 x 0.75 adaptor for Nikon or Canon cameras

3. Aluminium accessory handle

▶ and some friction sounds, implying it may be susceptible to knocks and marking over time. One thing that isn't flimsy is the machined tube ring, which holds the refractor snugly and securely.

Once attached to our mount, we found that the short Vixen-style foot allowed perfect and quick balance with an eyepiece fitted. On attaching a heavier DSLR camera, we couldn't move the scope forward enough to obtain balance. Sky-Watcher has designed for this, however, and we were able to remove and reposition the dovetail bar on our mount, allowing the Evolux to be mounted further forwards to achieve perfect balance.

Slewing over to our first target, we were pleased to find that focus could be easily achieved without the need for additional spacers – always a bonus. The dual-speed rack and pinion focuser was smooth but felt a little spongy, so fine adjustments were perhaps clumsy, but it held perfect focus all night.

Mini marvel

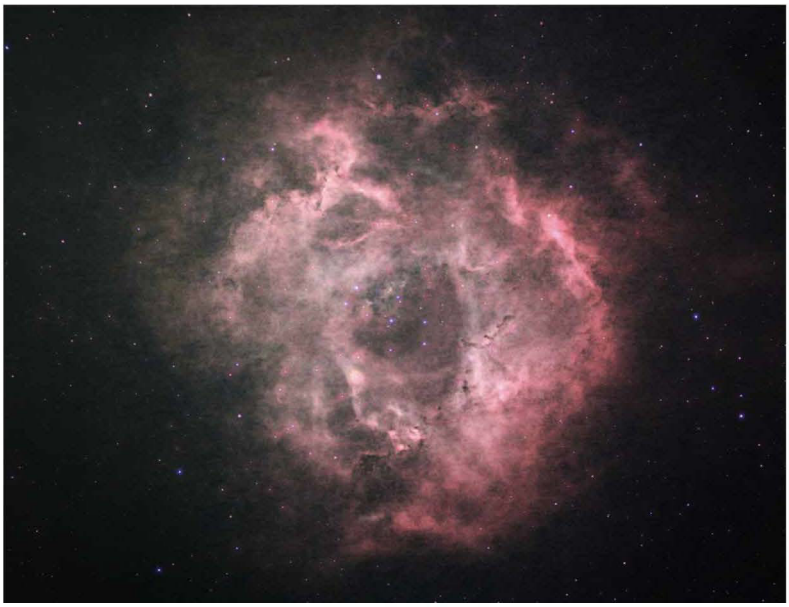
Running our first 30-second exposure revealed a very flat image that had round stars across the majority of the field, with mild vignette and stretched stars around the edge and in the corners. However, for this test we were using a full-frame camera, which can be challenging for high-end refractors. We then attached the optional matching field flattener/reducer, which was easy as it screwed directly onto the focuser barrel while our DSLR connected to the reducer. This gave a very solid connection, with no risk of slippage or of the camera falling. Once focused, we were pleased to see that with the wider field of view the stars were still mostly round, with only a slight vignette and curvature towards the corners.

We set our camera running for a night of imaging and then processed the images the following morning. Applying an initial stretch revealed some colour fringing and bloating around the brighter stars, but nothing that we couldn't correct and control. The stacked images revealed very crisp nebulae and a surprising amount of fainter detail for only an hour of exposure time per target. With calibration frames applied, vignetting was still evident in the corners, but the central area was beautifully uniform.

The Sky-Watcher Evolux ED82 as an entry-level refractor didn't disappoint, and provides everything budding astrophotographers and visual astronomers could ask for. It's a petite deep-sky refractor looking to deliver big performance.

Carry case

The lightweight but solid carry case makes the Evolux ED82 a perfect grab-and-go. It measures under 50cm in length and includes extra storage for multiple eyepieces, diagonal and filter cases. The case plus OTA weighs a little over 3kg, making this a very portable setup.



▲ Fine detail and pleasingly round stars were achieved in the Rosette Nebula when paired with a full-frame Canon 6D. ISO 1600, 162x 30"

▲ The Orion Nebula captured using the same setup. ISO 1600, 149x 30"

VERDICT

Build & design	★★★★½
Ease of use	★★★★½
Features	★★★★½
Imaging quality	★★★★½
Optics	★★★★½
OVERALL	★★★★½

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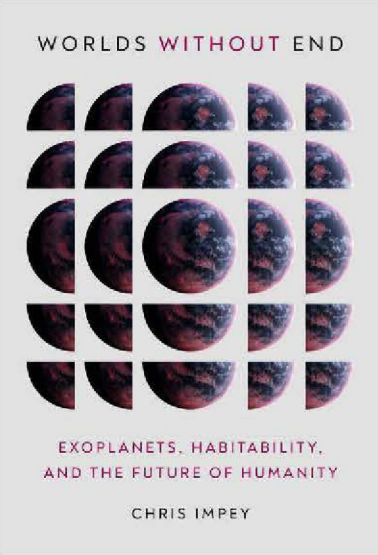
New astronomy and space titles reviewed

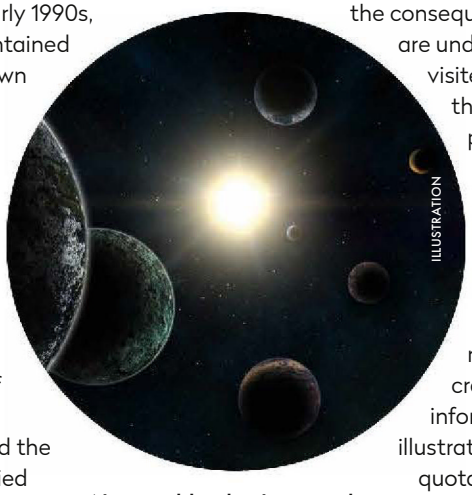
BOOKS



Worlds Without End

Chris Impey
MIT Press
£27 ● HB

As recently as the early 1990s, our Solar System contained the only planets known to us and Earth seemed the only possible haven for life. To say that the last three decades have changed this outlook would be a massive understatement. Today, thanks to an array of ground- and space-based telescopes and the individuals who lobbied for, built, operated and analysed data from them, over 5,000 planets have been identified beyond our Solar System. Of these, almost 200 are rocky, terrestrial planets like Earth and many are at a favourable distance from their star to harbour liquid water – a requirement for life as we know it and hence used as an indicator of habitability. Indeed, observations of our stellar neighbourhood so far point to there being more planets than stars. This means we might expect several hundred billion planets in our own Galaxy and perhaps similar numbers in other galaxies across the Universe. With so many planets out there, is Earth really that unique after all?



ILLUSTRATION

New world order: Impey takes a planet-hopping tour of the latest exoplanet science

OORKA/ISTOCK/GETTY IMAGES

This question, and ultimately the implications of its answer for humanity's survival, is at the very heart of *Worlds Without End*. Chris Impey takes the reader on an expertly navigated whirlwind tour of the fast-paced field of exoplanets. Early chapters describe the methods and telescopes used to discover exoplanets and the different types that have been found so far, while later chapters consider whether they might be habitable (or indeed already inhabited), how we might determine this with new telescopes and future spacecraft, which ones we should focus such a search on, and what technological developments are needed to visit and ultimately colonise them. The damage we are doing to Earth and the consequences we are facing are underlying themes visited at several points throughout and provide the motivation to search for the new home we may eventually need. *Worlds Without End* is a fascinating read that is crammed with information. Helpful illustrations and insightful quotations pepper the text and have been skilfully crafted into a captivating and accessible narrative capable of bringing all readers up to speed on this exciting and quickly evolving topic. ★★★★★

***Penny Wozniakiewicz** is a lecturer in space science at the University of Kent*

Interview with the author
Chris Impey

Are habitable worlds common?

About half of all exoplanets are Earth-sized or a little larger, and many are habitable. Habitability is defined as any planet at a distance from a star where liquid water could exist on the surface. There are more planets than stars in the Milky Way and the 5,300 or so exoplanets discovered so far project to about 10 billion habitable worlds in the Galaxy. Most will be orbiting red dwarf stars rather than stars like the Sun.

How do we find them?

The goal is to find habitable planets close enough to Earth to 'sniff' their atmospheres to detect life. NASA's Kepler mission found many good candidates, but they're hundreds of lightyears away. The TESS (Transiting Exoplanet Survey Satellite) mission will find better examples within 50 lightyears. Moons of giant exoplanets may also be habitable and methods may soon be good enough to detect exomoons.

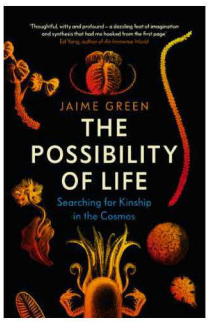
Can we assume life exists beyond our Solar System?

It is a good bet that Earth is not the only planet with biology. The chemical ingredients for life exist throughout the Universe and there is a vast amount of habitable 'real estate' in the Milky Way and all other galaxies. Even if not all habitable exoplanets host biology, odds are that many do. All life on Earth stems from a single biological experiment. It's an exciting possibility that life beyond Earth may have a different genetic basis than life on Earth.

***Chris Impey** is a University Distinguished Professor of Astronomy at the University of Arizona*

The Possibility of Life

Jaime Green
Duckworth
£20 ● HB



Rooted in our current golden age of exoplanet discovery, *The Possibility of Life* is a chronicle of humankind's relationship with the idea that we might not be alone in the Universe.

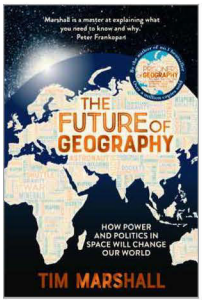
The search for alien life is on the bleeding edge of scientific understanding. With so many unknowns, author Jaime Green brings all hands on deck, interviewing dolphin communication experts, synthetic biologists, scientific illustrators, astrophysicists, historians and more. Beginning with ancient Greek theories of cosmic pluralism, the narrative weaves from origin-of-life studies through technology and the singularity. When imagining aliens, Green recognises that science fiction has done a lot of the legwork. In tandem with her scientific sources, she cites the film *Arrival* for linguistic challenges, *Avatar* for convergent evolution and the *Broken Earth* book trilogy for the importance of our Moon. Fittingly, Green reaches the same answer that both scientists and science fiction writers often find: in learning about the alien – other worlds, other life – we are really learning more about ourselves and our Earth.

The effect is breathtaking and the huge quantity of research in the book impressive; all the more so because Green's writing remains engaging and clear even as she never shies away from a complicated concept. *The Possibility of Life* is an excellent and accessible primer on science's efforts to answer an age-old question, and is recommended to anyone who has looked up and wondered if anyone is looking back. ★★★★★

***Emma Johanna Puranen** is an exoplanet science researcher*

The Future of Geography

Tim Marshall
Elliot and Thompson
£20 ● HB



Sixty years ago, the Space Race began with a bang, but in *The Future of Geography*, foreign affairs writer Tim Marshall argues that we humans now stand on the brink (or perhaps the precipice) of an entirely new Space Race: one dominated by nations, entities and individuals jostling for supremacy, not just of space's high ground, but of much more besides.

Marshall furnishes a whistlestop tour of our ageless fascination with the night sky, whose mysteries were depicted by our ancestors in prehistoric carved animal bones, artwork and deeply entrenched mythologies. He traces our gradual understanding of the heavens above, leading the reader to the bitterly ironic origins of the first space age, when rockets of peaceful intent were perversely twisted into bellicose tools of war.

His prose is brisk in pace and refreshingly crystalline in its clarity, affording a highly readable lesson in historical geopolitics. But as its title suggests, the history part is merely an entrée dish, as Marshall explores the influences and rivalries endemic in today's 'astropolitics' as they spill their earthly discord not only into space, but to the Moon and far beyond, into the Solar System's mineral-rich depths.

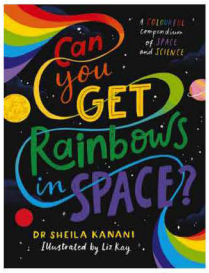
In this deeply thought-provoking volume, *The Future of Geography* draws parallels with advances made by land and sea power in redrawing 19th-century geopolitical maps. So too, Marshall writes, will space power redraw future maps. "Each time humanity has ventured into a new domain," he sagely writes, "it has brought war with it." On this point, we can hope Marshall has got it wrong. ★★★★★

***Ben Evans** is the author of several books on human spaceflight*

Can You Get Rainbows in Space?

KIDS' SCIENCE

Sheila Kanani, Liz Kay
Puffin
£14.99 ● HB



In this journey through the visible spectrum – and a little beyond – astronomer, planetary scientist and outreach officer for the Royal Astronomical Society Sheila Kanani introduces younger readers to colourful concepts across physics, biology, art, history and more.

Each chapter of the book is based on a different colour of the rainbow, the pages bursting with brilliant illustrations composed by Liz Kay. We're given an overview of each of the colours, which delves into the science of the particular wavelength, as well as giving us facts about that colour's use around the world. For example, did you know that, when viewed from a distance, yellow is the colour most visible to the human eye? That's why warning signs and high-vis jackets are bright yellow.

With clear and accessible descriptions of some tricky topics, Kanani answers questions that many budding scientists will have certainly asked themselves at one time or another. Why is Mars called the Red Planet? Why is the sky blue? And which came first, the colour orange or the fruit? She also of course addresses the question in the title and explains how to make a rainbow in space.

Can you Get Rainbows in Space? is recommended for children aged 7–9, although some of the concepts discussed in the book may be a little demanding for readers in that age group, like the electromagnetic spectrum and the differences between rod and cone cells in our eyes. Still, there is plenty that will grab the attention of young and old. At age 27-and-a-half, I learned that the primary colours in the visible light spectrum are not the same as those taught by my school art teacher! ★★★★★

***Amy Arthur** is a science author and public speaker*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Baader 2-inch Cool-Ceramic safety Herschel prism Mark II

Price £495 • **Supplier** The Widescreen Centre • **www.widescreen-centre.co.uk**

ADVANCED Observe the Sun safely in white light using this Herschel prism with its 2-inch barrel and eyepiece holder. It has an integrated rotation mechanism to use with polarising filters to adjust your view's brightness.

2 Altair Sabre mount v3.0

Price £385 • **Supplier** Altair Astro • **www.altairastro.com**

This altaz mount lets you to attach two telescopes side by side. Designed to be easy to use with practically no set-up time or need for alignment, this new version has easier-to-grip machined knobs.

3 Scruffs LED beanie hat

Price £13.95 • **Supplier** Scruffs • **www.scruffs.com**

Keep warm through the night without having to worry about finding your torch as this beanie hat has an in-built white LED light that's charged via USB.

4 Astro Essentials 4-port dew controller

Price £85 • **Supplier** First Light Optics • **www.firstlightoptics.com**

Independently adjust up to four dew heater strips (sold separately) with this controller. It supplies up to 8 amps when attached to an external power source using the 2-metre cigarette-lighter-style plug.

5 Gingko smart galaxy globe light

Price £149 • **Supplier** Farrar & Tanner • **www.farrar-tanner.co.uk**

Fill your room with a celestial glow with this unusual lamp. The globe is textured to resemble the cratered surface of an alien planet, printed with the majestic hues of a nebula. When turned on, the globe appears to magically hover and rotates slowly over its base.

6 StellaLyra 10mm ultra flat field 1.25-inch eyepiece

Price £79 • **Supplier** First Light Optics • **www.firstlightoptics.com**

If you want pin-sharp stars across your entire view, this might be the eyepiece for you. Its entire 60° field of view has excellent curvature and colour correction to give you the best view wherever you look.

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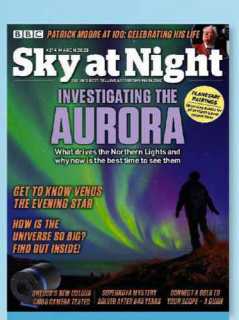

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Anita Chandran interviews Pavel Mancera Piña

Q&A WITH A DARK MATTER DETECTIVE

If dark matter accounts for a huge amount of the matter in our Universe, why do some galaxies appear to contain almost none of it?

What is dark matter and why is it called 'dark'?
We have evidence suggesting that there should be a certain amount of mass in the Universe, but this mass cannot be observed directly. Even in early works from the 1920s, astronomers knew that in order to explain how fast some galaxies move there needed to be more mass than we could account for. An astronomer called Fritz Zwicky came up with the name 'dark matter', but essentially the name only reflects that we don't really know what it is.

▲ **Thinly spread and ghostly dim, ultra-diffuse galaxies buck the trend by holding little or no dark matter**

NASA/ESA AND P. VAN DOKKUM (YALE UNIVERSITY)

What do we think dark matter might be made of?
Most of the community – not all – believes that dark matter is made of particles that don't interact with electromagnetic radiation, instead only interacting with normal matter through gravity. Essentially, it doesn't absorb or emit light (and heat). We can only infer that it's there due to gravitational effects. The problem is that although we have built experiments like the Large Hadron Collider, we haven't been able to detect dark matter particles, so we don't know what their exact properties are.

How do you look for dark matter?
By looking at how fast galaxies rotate. We know the rotation of a galaxy is a consequence of its total mass, so if we can observe how fast a galaxy rotates, then we know its total mass. We can compare the total mass measured from how fast the galaxy rotates with the mass of stars and gas [in the galaxy], which we can observe directly from telescopes. We can then look at the mismatch between the two to infer how much dark matter there is in the galaxy. There is typically a very strong mismatch, suggesting that there is a lot of mass that we don't see.

And what do your investigations show?
Our team was looking at a galaxy that was very peculiar because it's classified as an 'ultra-diffuse' galaxy. These galaxies are a bit weird because the distribution of light within them is similar to big spiral galaxies like Andromeda or the Milky Way. But they have about 1,000 times less stellar mass than big galaxies. Some people say they have the mass of dwarf galaxies, but the size of giants. We observed the motion of gas in one of these galaxies using the Very Large Array, a set of antennae in New Mexico, to obtain very sharp images. We measured how fast the gas is rotating in this galaxy. And then we tried to see how much dark matter there was. Usually, when you look at small galaxies, you find that most of the mass is dark matter. Perhaps 90 per cent, maybe 80 per cent. We found instead that there was a very small contribution from dark matter in this galaxy. In fact, if you take the numbers, you could argue that you don't need dark matter to explain how fast the galaxy is rotating.

Why do these ultra-diffuse galaxies have so little dark matter?
According to our understanding of galaxy formation and evolution, all galaxies should have dark matter. So if you see a galaxy with little dark matter it's very puzzling, though there are some mechanisms that could explain it. We think a potential explanation is that the galaxies have dark matter but that its density is very low. This tells us that the distribution of dark matter in these galaxies – if there is dark matter – should be very atypical and completely different to what we expect from our models of galaxy formation and evolution.

What are the implications of galaxies with little to no dark matter?
They challenge the norm in different aspects. Perhaps they are telling us that the distribution of dark matter in galaxies is much broader than what we would have expected. Or perhaps they are telling us that there are other mechanisms that can produce low dark matter densities. I think what is very exciting is that we can use these observations to infer the dark matter content, and perhaps these galaxies can tell us something about the nature of dark matter itself.

Pavel Mancera Piña is a postdoctoral researcher at Leiden Observatory in the Netherlands, specialising in dark matter

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Catch the Moon escorting five planets across the sky and spy the sparkling Gem Cluster in Carina

When to use this chart

1 May at 00:00 AEST (14:00 UT)
15 May at 23:00 AEST (13:00 UT)
31 May at 22:00 AEST (12:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

MAY HIGHLIGHTS

This month sees all five naked-eye planets visited by the Moon. On 14 May, Saturn and the Moon rise together around 01:00 (local time). On 17 May its thin crescent is visible 8° above Jupiter in the eastern predawn sky. The next day, it is 5° below Jupiter, with Mercury 3° to the right. The Moon then passes the Sun, reappearing in the evening. On 23 May there is a brilliant conjunction with its thin phase 4° below Venus. On the following two nights see it 7° from reddish Mars.

STARS AND CONSTELLATIONS

Riding high in the evening sky is one icon of the Southern Hemisphere, the Southern Cross (Crux). Crux has the most southerly first-magnitude star, Acrux, and is also the smallest constellation. It marks the most southerly part of the Milky Way too. The region between Crux and the False Cross asterism (20° westward) contains a wealth of star clusters, capped off by the Eta Carinae star cluster/nebula complex, clearly visible to the unaided eye and breathtaking through binoculars.

THE PLANETS

The evening sky this month belongs to Venus and Mars. Venus can't be missed low in the west-northwest, with Mars to its upper right. The planets draw closer together during May, both passing the twin stars of Castor and Pollux. Saturn rises around midnight (mid-month), with Neptune following two hours behind. Having now risen out of the dawn glow, Jupiter returns to the morning sky. Mercury follows hot on its heels and is best observed in the latter half of May.

DEEP-SKY OBJECTS

This month, a trip to Carina. Only 2° northwest of the Eta Carinae Nebulae lies NGC 3293 (RA 10h 35.8m, dec. −58° 13'), one of the brightest (mag. +4.7) and most striking open clusters in southern skies. Named the 'Gem Cluster', it's dominated by a dozen seventh-magnitude stars, all a brilliant blue except for an outstanding red member on the southwest corner. This compact, 5-arcminute group appears roughly square in shape.

Half-way between NGC 3293 and Eta Carinae is the double star HR4179 (RA 10h 39.0m, dec. −58° 49'), with components of mag. +6.2 and +8.0 separated by a comfortable 25 arcseconds. Lying within the same low-power field (0.4° south) is another double, HR4177, with its mag. +4.9 and +7.5 members closer at 15 arcseconds. Both of their primaries are red supergiants, offering wonderful colour contrast to their white companions.

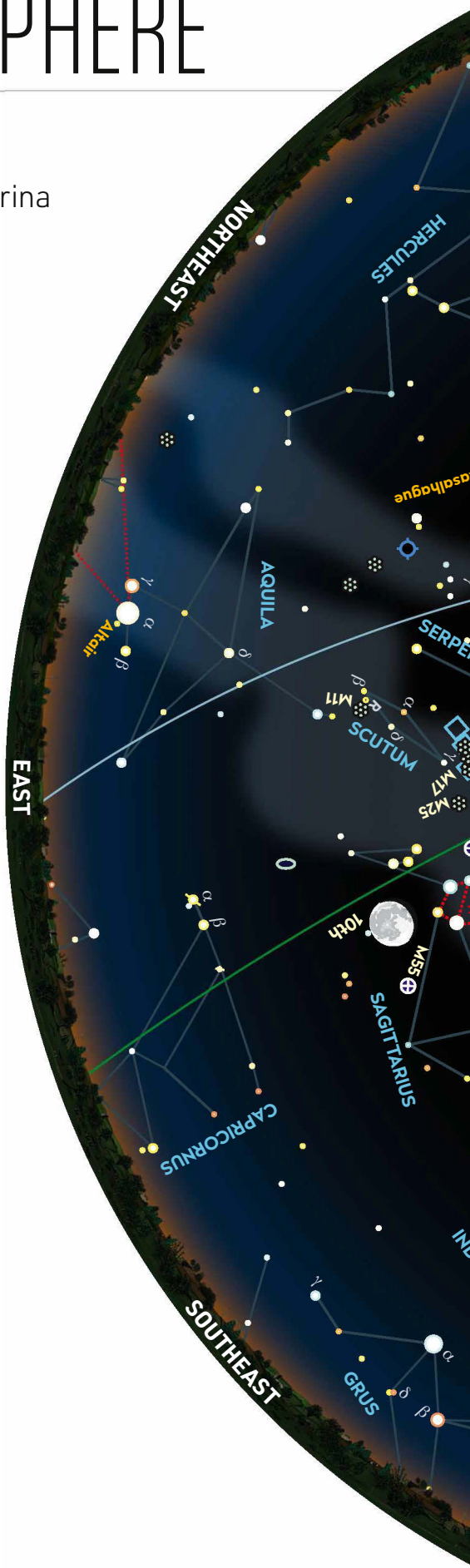

Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
BOÖTES
CANES VENATICI
CORONA BOREALIS
COMA BERENICES
URSA MAJOR
LEO
VIRGO
OPHIUCHUS
SERPENS CAPUT
LIBRA
CORVUS
CRATER
HYDRA
CENTAURUS
LUPUS
SCORPIUS
NORMA
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VOLANS
HYDRUS
TUCANA
MENSA
DORADO
PICTOR
RETICULUM
Keystone
Kite
Arcturus
Rasalgethi
Cor Caroli
Diadem
Sickle
Regulus
Spica
Antares
Alphard
Ghost of Jupiter
Celestial Equator
Ecliptic
1st
28th
31st
4th
7th
Leo Triplet
Jewel Box
Acrux
Coal Sack
Eta Carinae Complex
NGC 3293
HR4179
False Cross
South Celestial Pole
Tarantula Neb
Canopus
Achernar
Peacock Star
SMC
LMC
47 Tuc
M92
M13
M51
M106
M63
M94
M3
NGC 4565
M64
M53
NGC 4762
M60
M87
M86
M59
M66
NGC 4754
M5
M104
M83
ω Cen
M80
M4
M12
M10
M16
M23
M20
M8
M6
M7

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